The role of leadership in technology adoption in the South African mining industry

by P.J. Mokganya[1], R.C.W. Webber-Youngman[1], J. Uys[1*], and J. Olwagen[2]

Affiliation:
[1]Department of Mining Engineering, University of Pretoria, South Africa
[2]Johan Olwagen and Associates, South Africa

*Deceased

Correspondence to:
R.C.W. Webber-Youngman

Email:
ronny.webber@up.ac.za

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ORCiD:
R.C.W. Webber-Youngman
http://orcid.org/0000-0002-0101-7125

Abstract

This article discusses the critical role of leadership in the technology adoption process within organizations, particularly in industries like mining, where innovation is essential for maintaining competitiveness and operational efficiency. It highlights the limitations of traditional technology adoption models, such as the Technology Acceptance Model (TAM), Diffusion of Innovations (DOI), and Unified Theory of Acceptance and Use of Technology (UTAUT), which focus on individual factors and overlook the strategic and organizational roles of leadership.

The study proposes the Ambidextrous Leadership-Technology Adoption (ALTA) model, which integrates leadership styles such as transformational, transactional, adaptive, and ambidextrous leadership into the technology adoption process. The model emphasizes the balance between exploration (fostering innovation) and exploitation (ensuring operational efficiency). The findings suggest that transformational leadership fosters innovation by encouraging risk-taking and creativity, while transactional leadership ensures efficient technology integration.

The article also identifies key barriers to technology adoption, such as organizational resistance to change, which can be mitigated through adaptive leadership that addresses employee concerns. The research emphasizes the importance of a supportive organizational culture and cross-functional collaboration, which are essential for successful technology adoption. The study concludes by offering practical recommendations for leaders to foster a culture of innovation, manage resistance, and balance short-term efficiency with long-term technological advancement.

Keywords

leadership, technology adoption, innovation, ambidextrous leadership, transformational leadership, transactional leadership, organizational culture, mining industry

Introduction

Innovation is the process of developing new ideas, products, or processes, or the significant improvement of existing ones (Lopes-Claros, 2010; Tidd, 2001). In the South African mining industry, innovation is critical for transforming operational and strategic practices through processes such as digitization, real-time monitoring, data analytics, and automation, which are key drivers of the Fourth Industrial Revolution (Deloitte, 2018).

The industry faces significant challenges, including declining mineral grades, deeper deposits, and high-pressure work environments. Consequently, there is an imperative need for increased production efficiency, reduced unit costs, improved ore quality, enhanced safety measures, and compliance with environmental regulations to ensure sustainability (Alem et al., 2012), underscoring the necessity of innovation and adopting new technologies for the industry's viability.

Technology adoption encompasses the acceptance and utilization of innovations within organizations. It refers to a process through which individuals, organizations, or entire markets embrace and begin using new technologies. Rogers (2003) delineates the technology adoption process into three distinct stages, namely development of the innovation, trial testing by early adopters, and wider implementation of the innovation, respectively, interpolated as development, implementation and application by the authors.

➤ There are various technology adoption models in literature, derived with the purpose of providing a structured framework for understanding how individuals, groups and organizations adopt and integrate new technologies. These models help describe the factors that influence the adoption process, predict user behaviour and guide decision making for successful introduction of new technologies.

- The current existing models have limited focus on the influence of leadership. Most technology adoption models (e.g., Technology Acceptance Model (TAM), Diffusion of Innovation (DOI)), primarily emphasize individual-level factors, like perceived usefulness and ease of use, but they downplay or ignore the role of leadership in setting strategic direction, creating a vision for technology, or driving adoption initiatives. Leadership's role in fostering a technology-friendly culture and motivating employees to embrace new technologies is often underrepresented. Leadership styles such as transformational, transactional, or servant leadership significantly impact how technology is adopted within organizations (Bossink, 2007; Gilley et al., 2008, Rossing et al., 2011). Current models do not adequately capture how different leadership approaches influence adoption rates. For instance, transformational leaders who inspire and encourage innovation may accelerate adoption, while transactional leaders focused on short-term performance may slow it down (Bass, 1990).
- Adoption models rarely address how leadership aligns new technologies with the broader organizational strategy (Tornatsky et al., 1990). Leaders often evaluate whether a new technology fits with long-term business goals, and their decision to adopt may depend on whether it supports strategic objectives, such as digital transformation or operational efficiency (Westerman et al., 2014).

Aim of the article

Research into leadership and technology adoption has become a critical topic in the current volatile, uncertain, complex and ambiguous (VUCA) environment the world is currently experiencing. This article aims to address benefits and the limitations of current technology adoption models by emphasising the critical role of leadership in shaping the adoption of new technologies within organizations. It seeks to explore how various leadership styles - transformational, transactional, and ambidextrous leadership- impact technology adoption rates and foster a culture conducive to embracing innovation. To address the central research question of what role leadership plays in technology adoption, this article will propose a comprehensive framework that directly integrates leadership dynamics with the technology adoption processes. This framework will illustrate how leadership influences technology alignment with organizational strategies, ultimately enhancing understanding of the interplay between leadership, innovation, and strategic objectives. The main purpose of the research is to establish the relevance of the ambidextrous leadership-technology adoption (ALTA) model, which seeks to address gaps such as the direct role of leadership in technology adoption.

Technology adoption

- Technology adoption refers to the process by which people or organizations accept and use new technologies. The technology adoption process can be described in three phases, namely **development phase, implementation phase** and **application phase**. The **development phase** focuses on the creation and design of technology. During this stage, activities such as research and development (R&D), idea generation, and prototyping take place. This phase is characterized by high uncertainty and involvement of innovators and early adopters, who test and refine the technology for broader use (Rogers, 2003).
- In the **implementation phase**, organizations adopt and integrate the developed technology into their workflows or processes. This stage involves configuring infrastructure, training personnel, and making operational changes (Cresswell and Sheikh, 2013). A key challenge during this phase is overcoming resistance to change and manage unforeseen technical challenges. The quality of implementation often determines the eventual success or failure of technology adoption (Venkatesh et al., 2003).
- The **application phase** refers to the routine use of technology in daily operations. After successful implementation, organizations focus on optimizing the use of technology to achieve desired outcomes, such as improved productivity or cost efficiency (Davis, 1989).
- Technology adoption models aim to explain how individuals and organizations accept and use new technologies. Over time, various models have been developed to understand the factors that influence technology adoption. In this review, we explore four prominent technology adoption models: the Technology Acceptance Model (TAM), the Diffusion of Innovations (DOI) theory, the Unified Theory of Acceptance and Use of Technology (UTAUT), and the Technology-Organization-Environment (TOE) framework. We will also examine the limitations of each model, particularly in relation to leadership's role in technology adoption.
- The **Technology Acceptance Model (TAM)** is one of the most widely applied models in technology adoption research. Developed by Davis (1989), TAM is grounded in the Theory of Reasoned action (TRA) and posits that two key factors, **Perceived usefulness (PU)** and **Perceived Ease of Use (PEOU)**, determine an individual's decision to adopt a new technology, as shown in Figure 1. PU refers to the extent to which a person believes that using a technology will improve their performance, while PEOU refers to the effort required to use the technology.

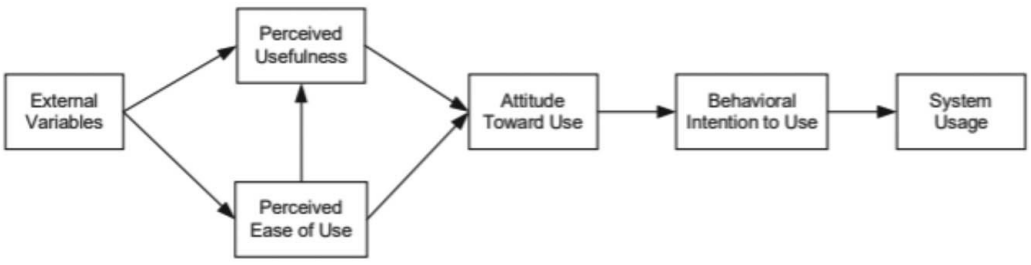

Figure 1—Technology Acceptance Model (Davis, 1989)

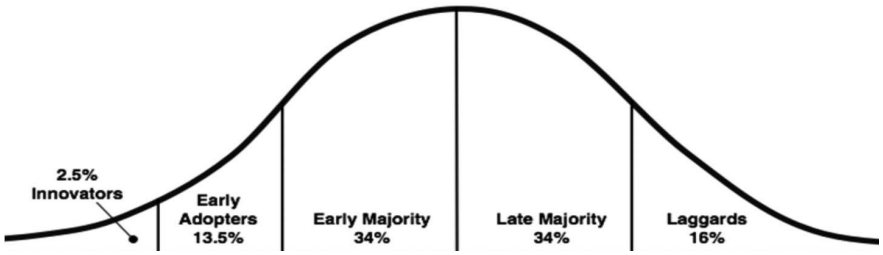

Figure 2—Diffusion of Innovation Curve (Rogers, 2003)

- **Shortcomings of TAM in relation to leadership:**
  - *Limited focus on external factors:* TAM emphasizes individual perceptions but does not account for external leadership-driven factors such as organizational culture, vision, and strategic direction.
  - *Lack of focus on collective decision-making:* Leadership often plays a significant role in shaping the collective decision to adopt new technologies (Yukl, 2013), but TAM primarily examines individual user behaviour.
  - *Does not consider organizational resistance or change management:* Leaders must manage resistance to change and facilitate smooth transitions to new technologies (Burnes, 2004). TAM does not offer a framework for understanding how leadership can overcome organizational resistance during the technology adoption process.
- The **Diffusion of Innovations (DOI)** theory, developed by Rogers (2003), explains how an innovation is communicated and spread over time within a social system. Rogers identified five categories of adopters: Innovators, early adopters, early majority, late majority, and laggards as shown in Figure 2. The adoption process is influenced by five main factors: Relative advantage, compatibility, complexity, trialability, and observability.
- **Shortcomings of DOI in relation to leadership:**
  - *Inadequate consideration of leadership influence:* DOI focuses on social systems and communication networks, largely ignoring the active role that leadership plays in driving adoption.
  - *Overemphasis on individual choices:* DOI emphasizes individual adoption behaviors without considering how leadership can influence collective organizational decisions and enforce strategic priorities.
  - *Does not address the dynamic role of leadership in facilitating adoption:* Leadership must actively guide the organization through phases of adoption, but DOI does not account for how leaders manage change or align technology with business objectives.
- The **Unified Theory of Acceptance and Use of Technology (UTAUT)**, developed by Venkatesh et al. (2003), integrates elements from various technology adoption models, including TAM, DOI, and the theory of planned behaviour (TPB), which explains how the behaviors of individuals are influenced by their intentions as well as the factors that shape those intentions (Ajzen, 1991). UTAUT identifies four key constructs: **Performance expectancy, effort expectancy, social influence, and facilitating conditions**. These constructs explain user intentions to adopt technology and subsequent usage behaviour.
- **Shortcomings of UTAUT in relation to leadership:**
  - *Minimal focus on leadership's strategic role:* UTAUT acknowledges social influence, but focuses mainly on peer pressure rather than the top-down influence of leadership on technology adoption.
  - *Limited insight into leadership's role in change management:* While facilitating conditions are considered in UTAUT, the model does not delve deeply into how leaders can proactively shape these conditions to drive technology adoption.

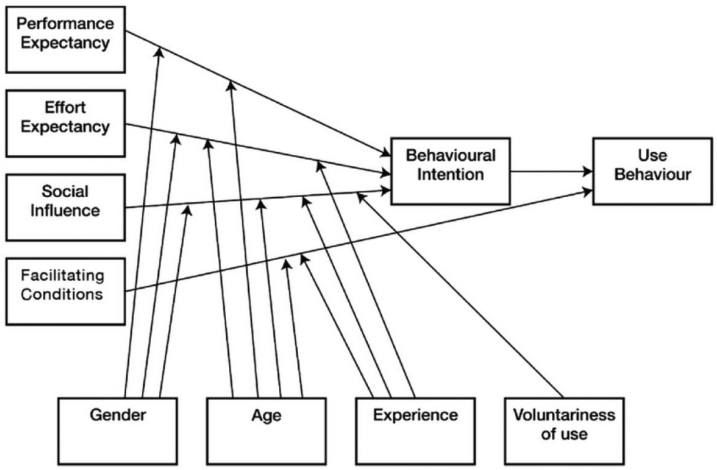

Figure 3—UTAUT Model (Venkatesh et al., 2003)

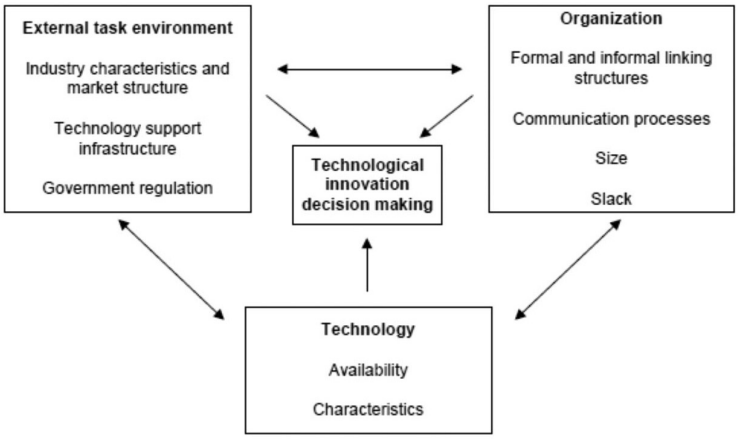

Figure 4—Technology-Organization-Environment Framework (Tornatsky & Fleischer, 1990)

- *Narrow focus on individual user behaviour*: Similar to TAM, UTAUT primarily targets individual-level factors, with little consideration for leadership-driven organizational strategy or how leaders create an environment conducive to adoption.

➤ The **Technology-Organization-Environment (TOE) framework**, proposed by Tornatsky and Fleischer (1990), suggests that technology adoption is influenced by three interrelated factors: **technological, organizational, and environmental contexts**. The organizational context includes internal processes, organizational size, and managerial structure, while the environmental context encompasses external forces such as competition and regulation.

➤ **Shortcomings of TOE in relation to leadership:**
- *Lacks a strong focus on leadership as a driving force*: While TOE considers organizational factors, it does not explicitly highlight the role of leadership in shaping organizational readiness or strategy for technology adoption.
- *Static view of organizational dynamics:* TOE assumes that organizational and environmental factors are relatively stable, but in practice, leadership plays a crucial role in dynamically responding to shifts in these factors (Yulk, 2013).
- *Limited guidance on leadership's role in fostering a culture of innovation*: Leaders often need to foster a culture of innovation and adaptability to facilitate technology adoption (Schein, 2010), but TOE does not provide a clear framework for how leaders can cultivate such a culture.

➤ The four technology adoption models reviewed, TAM, DOI, UTAUT, and TOE, offer valuable insights into the factors that influence the adoption of technology in organizations. However, each model has its shortcomings, particularly in relation to leadership. TAM and UTAUT emphasize individual behaviour, but overlook the organizational and strategic roles of leadership. DOI and TOE recognize broader organizational and environmental factors, but do not sufficiently explore the dynamic and pivotal role of leadership in driving and sustaining technology adoption.

Leadership

This research focused on integrating these leadership frameworks and models, to provide a more comprehensive understanding of technology adoption processes. To do so, a literature study of leadership styles was conducted. Different leadership styles can either foster or hinder innovation and the implementation of technological advancements. This review examines four key leadership styles namely: **Transformational leadership, transactional leadership, servant leadership, and adaptive leadership**, and their influence on innovation and technology adoption, highlighting relevant studies and their conclusions.

The choice of the leadership styles was influenced by considering leadership styles that tend to foster innovation. The styles discussed in this article are those that have support from multiple authors based on the work that they have done to prove their correlations to innovation, and/or denote their shortcomings thereof. The article combines the traits from each leadership style based on what is required per the technology adoption phase, because there is not just one leadership style that caters for the process of technology adoption.

➤ *Transformational leadership:* is one of the most studied leadership styles in relation to innovation. Introduced by Burns (1978) and further developed by Bass (1985), transformational leaders inspire and motivate their followers to achieve higher levels of performance and embrace change. These leaders focus on four key components: idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration.

➤ *Influence on innovation and technology adoption:* intellectual stimulation encourages creativity and out-of-the-box thinking, which is essential for innovation and technology adoption. Leaders who promote intellectual stimulation challenge the status quo and encourage experimentation (Bass, 1985).

➤ *Inspirational motivation fosters* a vision of the future that includes the adoption of new technologies, helping to align the organization's goals with innovative pursuits. Transformational leaders often act as change agents, creating a culture that embraces new technologies (Jung, Chow, and Wu, 2003). Their focus on vision and long-term strategic planning can make the transition to new technologies smoother and more aligned with organizational objectives. However, transformational leadership can face challenges in environments resistant to change, where employees or systems are rigid, as this style assumes openness to innovation.

➤ *Transactional leadership:* is characterized by a focus on clear structures, tasks, and rewards. Leaders using this style typically engage in an exchange process with followers: rewards for performance or penalties for underperformance.

Burns (1978) described it as a more managerial approach, where leaders maintain the status quo rather than encourage innovation.

- *Influence on innovation and technology adoption*: transactional leaders may be effective in ensuring efficient implementation of technology by offering clear guidelines and expectations, but they are less likely to drive the creative aspects of innovation.
- While transactional leadership promotes adherence to procedures and policies, it can stifle creativity and risk-taking, which are necessary for breakthrough innovations (Howell and Avolio, 1993). This leadership style may be suitable for managing incremental innovations but is less effective in fostering the adoption of disruptive technologies. The reward-punishment framework may create short-term gains in terms of technology adoption, e.g., meeting deadlines, but it often lacks the visionary approach needed to drive long-term, transformative innovation.
- **Servant leadership**, introduced by Greenleaf (1970), emphasizes the leader's role in serving their team and facilitating the growth and well-being of their followers. This leadership style focuses on empowering employees, encouraging collaboration, and prioritizing the needs of the team over the leader's personal ambitions.
- *Influence on innovation and technology adoption:* servant leaders tend to empower employees by fostering a participatory culture where all members are encouraged to contribute ideas. This empowerment creates an environment where innovation can thrive, as employees feel supported in proposing new technologies or approaches (Van Dierendonck, 2011).
- By promoting collaborative decision-making, servant leaders can drive the collective adoption of technology. This inclusive approach aligns with the concept of shared leadership, where innovation emerges from multiple sources within the organization rather than being directed solely by top management.
- When requiring adoption of innovation, servant leaders may find it challenging in enforcing this adoption. At times they may have difficulty in establishing their authority in the different phases of adoption of innovation (Mautz, 2021).
- **Adaptive leadership**, developed by Heifetz (1994), focuses on the ability of leaders to help organizations and individuals adapt to complex, changing environments. Adaptive leaders emphasize the importance of flexibility, learning, and adjusting strategies based on evolving circumstances. This style is particularly relevant to technology adoption, where ongoing change and adaptation are critical (Heifats, 2009).
- *Influence on innovation and technology adoption:* adaptive leadership encourages learning and experimentation, which are essential for technology adoption and innovation in dynamic industries. These leaders focus on the organization's ability to continuously evolve, thus creating an environment where technology is seen as a tool for long-term survival and competitiveness (Heifetz and Laurie, 1997). Adaptive leaders also promote a culture of resilience, helping teams navigate the uncertainties and complexities that often accompany the introduction of new technologies.
- One of the challenges for adaptive leaders is balancing short-term performance pressures with the need for long-term adaptation. In organizations where immediate results are prioritized, adaptive leadership might struggle to gain traction.
- **Ambidextrous leadership** is a relatively recent but important concept in leadership theory, particularly in relation to innovation and technology adoption. It refers to the ability of a leader to balance exploration (fostering innovation and creativity) and exploitation (maximising efficiency and optimizing existing processes) within an organization (Rosing et al., 2011). This dual capability is essential in environments characterized by rapid technological change, where both adaptability and operational excellence are required for success.

Concept of Ambidextrous Leadership

The term 'ambidexterity' in leadership derives from organizational ambidexterity, which was initially introduced by Duncan (1976) and later refined by scholars such as Tushman and O'Reilly (1996). Ambidextrous leadership involves the capacity to switch between two distinct leadership behaviours:

- Exploration-oriented leadership focuses on encouraging risk-taking, experimentation, and the search for new knowledge and innovation.
- Exploitation-oriented leadership emphasizes refining existing knowledge, improving efficiency, and maintaining consistent performance.

Ambidextrous leaders are expected to dynamically alternate between these behaviours depending on the context, ensuring that the organization is both innovative and efficient.

- *Exploration:* ambidextrous leaders encourage creative problem-solving, the exploration of new opportunities, and innovative thinking. They create environments that reward experimentation and tolerate failure as part of the innovation process (Raisch and Birkinshaw, 2008).
- *Exploitation:* at the same time, these leaders also promote the optimization of existing processes, cost-cutting, and performance improvement, helping the organization execute strategies more efficiently.

Influence on Innovation and Technology Adoption

Ambidextrous leadership is particularly relevant for organizations seeking to adopt new technologies, as technology adoption often requires both exploration (to identify, develop, and pilot new technologies) and exploitation (to implement, scale, and optimize those technologies effectively). The value of this leadership approach lies in the following:

- Ambidextrous leaders support radical innovation by promoting a culture of exploration. They encourage employees to challenge the status quo, experiment with new ideas, and pursue novel technologies that can create competitive advantages (Jansen et al., 2008).
- Leaders who excel at exploration are more likely to recognize disruptive technologies early and create cross-functional teams that collaborate on developing innovative solutions.
- Once new technologies are identified or developed, ambidextrous leaders must shift toward exploitation, focusing on the systematic implementation and integration of these technologies. This involves process optimization, resource allocation, and training to ensure smooth technology adoption.

Exploitation-oriented leadership ensures that the organization does not lose sight of operational goals while experimenting with new technologies. It allows leaders to balance short-term performance with long-term innovation.

- These leaders reduce uncertainty by implementing structures that help employees effectively integrate new technologies into their daily operations, thus enhancing the technology adoption process.

Several studies have provided empirical support for the effectiveness of ambidextrous leadership in promoting innovation and technology adoption:

- Rosing, Frese, and Bausch (2011) conducted a meta-analysis of leadership behaviors and innovation and found that ambidextrous leadership significantly improved innovation outcomes. The ability to foster both exploration and exploitation was linked to higher levels of organizational adaptability and success in technology adoption.
- Jansen et al. (2008) found that organizations led by ambidextrous leaders were better able to achieve incremental and radical innovations, enabling them to stay competitive in dynamic markets.
- Tushman and O'Reilly (1996) highlighted the importance of ambidextrous leadership in managing organizational ambidexterity and maintaining alignment between innovation and operational efficiency. They emphasized the role of senior leaders in orchestrating both short-term efficiency and long-term innovation.

Ambidextrous leadership is a highly effective style for organizations seeking to innovate and adopt new technologies. By balancing the need for exploration (innovation, risk-taking, and creativity) with exploitation (efficiency, control, and process optimization), ambidextrous leaders create an environment where new technologies can be both developed and implemented effectively.

Despite these strengths there are also certain shortcomings and challenges linked to this approach:

- **Balancing conflicting priorities:** leaders must be adept at managing the tension between exploration and exploitation to fully capitalize on the benefits of ambidextrous leadership. The ability to switch between these two leadership behaviors requires a high level of flexibility, contextual awareness, and organizational support, which can pose challenges for leaders and organizations alike. One of the main challenges for ambidextrous leaders is managing the tension between exploration and exploitation. Exploration involves risk-taking and uncertainty, while exploitation emphasizes efficiency and control. These two objectives can often be in conflict, making it difficult for leaders to balance them effectively (O'Reilly and Tushman, 2013).
- **Organizational structure:** ambidextrous leadership requires an organizational structure that supports both exploration and exploitation. Some organizations may find it difficult to implement the dual structures needed to support innovation while maintaining operational efficiency.
- **Leadership flexibility and adaptability:** ambidextrous leaders need to be highly adaptive and flexible, as they must switch between different leadership behaviors based on changing organizational needs and environmental conditions. Not all leaders possess the skill or agility to navigate this dynamic leadership style effectively (Rosing et al., 2011). Additionally, ambidextrous leadership requires contextual awareness, meaning that leaders must be able to read signals from their environment and know when to emphasize exploration versus exploitation.

Conceptual model (Theoretical framework developed from literature)

The conceptual model that follows, aims to integrate the principles of technology adoption and leadership styles, addressing the shortcomings identified in both areas. The model builds on the strengths of existing technology adoption frameworks (TAM, DOI, UTAUT, TOE) and incorporates leadership styles (transformational, transactional, servant, adaptive, and ambidextrous leadership) to enhance the effectiveness of innovation and technology adoption within organizations.

This integrated model, called the Ambidextrous Leadership-Technology Adoption (ALTA) model therefore seeks to address gaps such as the direct role of leadership in technology adoption, the role of leadership in overcoming resistance, and the need for dynamic leadership styles that balance innovation with efficiency, consideration of all factors that influence the technology adoption (TA) process: external (societal factors and individual behaviour), and internal (organizational readiness), as shown in Table I.

Key Components of the ALTA Model

The ALTA model is composed of three interconnected layers: leadership drivers, technology adoption phases, and organizational outcomes. Each layer interacts with the others, creating a comprehensive framework for guiding technology adoption.

Leadership drivers: at the core of this model is leadership, as leaders play a pivotal role in both fostering innovation and facilitating the adoption of technology. The ALTA model integrates key leadership styles that are most relevant to technology adoption, with a focus on balancing exploration and exploitation through ambidextrous leadership.

- **Exploration-oriented behaviours (innovation and adaptability):** based on transformational, adaptive, and ambidextrous leadership styles, leaders are tasked with promoting creativity, encouraging risk-taking, and fostering innovation within the organization.
  - *Vision setting*: transformational leaders articulate a compelling vision of the future, including the strategic importance of adopting new technologies.
  - *Intellectual stimulation*: leaders encourage innovation and out-of-the-box thinking to identify new technologies and potential disruptive changes.
  - *Organizational learning*: adaptive leaders ensure that the organization remains flexible, fostering continuous learning and experimentation in rapidly evolving technological landscapes.
- **Exploitation-oriented behaviours (efficiency and implementation):** this includes transactional, servant, and ambidextrous leadership elements, focused on ensuring efficient implementation and operational excellence.
  - *Process optimization:* transactional leaders enforce structure and guidelines to ensure the smooth integration of new technologies into existing workflows.
  - *Empowerment and support:* servant leaders support employees by providing the necessary resources and training for them to adopt new technologies confidently.

Table I

Ambidextrous leadership-technology adoption conceptual Mmodel

Technology adoption phase	Development (Exploration)	Implementation (Transition)	Application (Exploitation)
Leadership style	• Transformational	• Ambidextrous	• Transactional
Leadership characteristics	• Charismatic • Visionary • Courageous • Persuasive • Good communicator	• Flexible • Adaptable • Contextual awareness • Collaborative	• Less experimental • Focus on clear structures • Prioritizes routines • Prioritizes meeting deadlines
Leadership actions	• Organization learning and determining readiness • Set strategic vision • Intellectual stimulation • Create innovation task forces • Identify new technologies • Consider the perceived use of the technology • Consider the characteristics of the adopter • Evaluate the feasibility of the innovation	• Facilitate cross-functional collaboration • Stakeholder engagement • Obtain buy in from stakeholders • Reduce resistances toward the technology • Change management • Resource allocation	• Provide training • Optimize resource allocation • Establish monitoring systems • Monitor for continuous improvement • Establish reward systems for successful adoption • Ensure organizational efficiency

- *Facilitating conditions*: leadership ensures that adequate support structures (such as IT infrastructure, funding, and organizational alignment) are in place to facilitate the use and scaling of new technologies.

The ALTA model integrates a dynamic, multi-phase technology adoption process. Each phase is influenced by leadership drivers that are aligned with different styles and behaviors to overcome the shortcomings of traditional technology adoption models.

Phase 1: Development - Technology identification and innovation (Exploration)

➤ **Leadership role:** transformational and adaptive leadership styles dominate in this phase, as leaders foster a culture of innovation and exploration. Leaders encourage employees to identify emerging technologies and evaluate their potential for driving competitive advantage.

- *Leadership action:* set strategic visions for technology, create innovation task forces, and encourage employees to take calculated risks.
- *Outcome:* organizations generate creative ideas, identify new technologies, and explore how these innovations align with the organization's future goals.

Phase 2: Implementation - Decision-making and buy-in (Transitional)

➤ **Leadership role:** here, ambidextrous leadership becomes critical as leaders must balance exploration and exploitation. Leaders facilitate discussions across organizational levels to achieve consensus on which technologies to adopt.

- *Leadership action:* facilitate cross-functional collaboration, ensure that all relevant stakeholders are involved in decision-making, and provide evidence of how new technologies align with organizational strategy.
- *Outcome:* consensus is built around which technologies to adopt, with buy-in from key stakeholders at all levels of the organization.

Phase 3: Application - Integration (Exploitation)

➤ **Leadership role:** exploitation-oriented leadership styles such as transactional and servant leadership dominate. Leaders ensure that technology is seamlessly integrated into operational processes, with minimal disruption to the day-to-day functioning of the organization.

- *Leadership action:* provide training, establish monitoring systems, and reward employees who successfully adopt and use new technologies. Leaders focus on optimizing resource allocation and ensuring organizational efficiency during the adoption phase.
- *Outcome:* the organization successfully integrates the new technology into its operational framework, minimizing resistance and maximizing efficiency.

Expected/envisaged organizational outcomes

➤ Successful technology adoption is measured by several key outcomes, which are influenced by leadership behaviour throughout the adoption process:

- *Innovation performance:* the organization is more innovative, consistently identifying and adopting new technologies that drive competitive advantage.
- *Operational efficiency:* the organization is efficient in implementing technologies, with optimized processes and minimal disruption during technology integration.

- *Employee engagement and empowerment:* employees feel empowered and supported throughout the technology adoption process, contributing to a culture of continuous improvement and innovation.
- *Adaptability and resilience:* the organization becomes more adaptable to future technological changes and market shifts, able to pivot quickly when necessary.

➤ The ambidextrous leadership-technology adoption (ALTA) model integrates leadership styles with the technology adoption process to create a holistic approach to managing innovation and technological change. By focusing on both exploration and exploitation, and emphasizing the strategic role of leadership, this model addresses the key shortcomings of traditional technology adoption frameworks. It ensures that organizations are well-positioned to adopt new technologies efficiently, while fostering a culture of innovation and adaptability.

Methodological approach of ALTA Model 'Testing' (Relevance)

➤ A qualitative research design was selected to explore and test the conceptual model. This approach enables a detailed description of participants' experiences, providing a deeper understanding of the subject matter, which is crucial for empirical research. To gather data, qualitative interviews were conducted with officials from the mining industry who had worked on or led innovation projects. This empirical method of data collection is based on observation and experience rather than theory or pure logic (Jasti, 2014). This approach was essential to the study, as valuable insights into the research topic could only be gained through direct communication with experienced individuals in the field.

➤ The interviews were semi-structured, with most questions prearranged, while allowing flexibility for new ideas to emerge during the conversations. On average, the interviews lasted 45 minutes, and responses were recorded via notetaking, voice recording, and/or video recording on Google Meet, with participants' consent.

➤ An interview guide was developed and used to conduct interviews in a manner that addressed the main research question and sub-research questions. The questions were derived from the literature review. The guide began with an introduction of the interviewer and an explanation of the purpose of the interviews in relation to the research topic. Participants were then asked about their occupation, current roles in the mining industry or at their respective mines, the type of operation they work in (either underground or open cast), and their experience with innovation projects. These initial questions helped assess their level of competency and ability to provide insightful information regarding the research topic.

➤ Participants who had worked on an innovation project were asked to select one successful project as the basis for further questions. The project's success was determined by the full adoption of the technology across the organization. Participants who met these criteria proceeded to the next stage.

➤ Twenty individuals were approached to take part in the study, which included mine managers, general managers, technical services managers, relationship managers, chief executive officers, and managing directors from selected mines. Of these, nine responded, meeting the requirements for a phenomenological study, which typically calls for 5 to 25 interviews (Cresswell, 1998; Morse, 1994). Table II shows the various roles of the participants and the innovation projects they have driven.

Data analysis

The results of this study were analysed using **thematic analysis**, a qualitative method used to identify, analyse, and report patterns or themes within data, applicable to data such as interviews, focus groups, or written material (Braun, 2012). In this case, the data consisted of interview transcriptions.

A theme, in this context, refers to elements of the data that are relevant to the research question or show patterns across the dataset. However, a theme is not necessarily defined by how often it appears in the data. Instead, the researcher exercises judgment in determining what constitutes a theme (Braun, 2012). A theme was selected if it captured something significant related to the overall research question or sub-questions.

Table II

Roles of participants and innovation projects Driven

Participant	Role	Innovation project
1	Mechanical Engineer (Glencore)	Implementation of collision avoidance system
2	Head of Engineering (Glencore Coal)	Installation of proximity detection system
3	Vice President (SASOL Mining)	Digitization of the organization
4	Technical Manager (Glencore Coal)	Business optimization and improvement
5	M&R CEO (Underground Mining Division)	Digital technology implementation
6	Director of Marketing and Supply Chain	Autonomous blasting system
7	Production Manager	Introduction of remotely operated bolters
8	Project Manager	Introduction of remotely operated roof bolters
9	Mechanical Engineer	Installation of proximity detection system

This study emphasizes qualitative descriptions over quantifiable measures, using terms such as 'many participants,' 'most respondents,' or 'several participants' to convey the prevalence of certain themes. The authors used the thematic analysis process stipulated by Chap et al. (2012) and Braun (2012) described in the following phases:

Phases of the thematic analysis

1. **Familiarization:** The researcher immersed in the data through repeated reading and transcription of interviews.
2. **Generating Initial codes:** an initial list of codes was developed to identify features in the data relevant to the research questions.
3. **Searching for themes:** themes were identified by clustering related codes and recognizing patterns.
4. **Reviewing potential themes:** themes were reviewed for quality and coherence, ensuring they accurately represented the dataset.
5. **Defining and naming themes:** each theme was clearly defined, ensuring they collectively told a coherent story about the data.
6. **Producing a report:** the final phase involved compiling the results of the thematic analysis into a comprehensive report.

Qualitative findings for testing the ALTA Model: Results

The findings for this qualitative research study testing the **ambidextrous leadership-technology adoption (ALTA) model,** indicate how leadership behaviors influence various phases of the technology adoption process, how organizations manage innovation, and how ambidextrous leadership plays a role in balancing exploration and exploitation. These findings are based on themes that emerged from the thematic analysis of the interviews conducted, and are discussed as follows (includes quotes of the people interviewed as recorded):

Leadership influence on exploration and innovation

- **Theme 1:** Transformational Leadership Encouraging Exploration and Risk-taking
  - **Finding:** Interviewees often described leaders with transformational qualities—visionary, charismatic, and able to inspire innovation. They speak of how leaders encourage creative problem-solving and taking risks in identifying new technologies, creating an environment where employees feel empowered to suggest bold, innovative solutions.
- **Quote:** "*I'll give you a few keys that I think normally helps get to a new idea of innovation and to then move on with the project. The first one is vision. You need visionary leaders that will have a very clear picture and envisage the future. Vision is at the top of the list you know, without leaders that's got vision none of this [innovation] will ever happen.*"
- **Quote:** "*Leadership needs to be flexible and agile and courageous. You must be decisive in what you want to do, you must think on your feet and prepare for failure. When it fails, show agility, do something, and fix it. If you try to work out the perfect execution plan you will take too long. Procrastination will never get you anywhere.*"
- **Theme 2:** Ambidextrous Leadership Balancing Innovation with Operational Needs
  - **Finding:** Case studies highlight that ambidextrous leaders excel at maintaining a balance between exploration and exploitation. Employees note that these leaders not only encourage innovation but also set boundaries to ensure operational processes are efficient, preventing the chaos that can arise from too much focus on new technologies.
- **Quote:** "*Look I think flexibility should be high, I mean probably a four [out of 5], but you got to be careful. If you let the flexibility, get too high, you lose the effectiveness of the project. So, the system has to run, but when things come up that are better, unique, or different, you need to be quite flexible to accept them and adapt. You don't want to be completely flexible because if you do that, they're going to lose control of the process.*"

Leadership influence on implementation and efficiency

- **Theme 3:** Transactional Leadership Promoting Structured Implementation
  - **Finding:** In interviews and focus groups, participants describe transactional leaders as vital during the implementation phase of technology adoption. These leaders focus on setting clear goals, timelines, and expectations, which helps ensure that technology is integrated smoothly into the organization.
- **Quote:** "*Once they have gotten all the parties together, put an implementation plan together that needs to include all the details about the collaboration, including the non-technical side of it. Ensure that the plan covers everything that it needs.*"
- **Quote:** "*The other important part of the implementation process is the management of change. As you start implementing, things do not necessarily go to plan. As you start implementing your plan, be flexible enough to change.*"
- **Theme 4:** Overcoming Resistance to Change through Leadership
  - **Finding:** Participants highlighted the role of adaptive and transformational leadership in managing resistance to new technologies. These leaders communicate the long-term benefits of adoption, making employees feel more comfortable with the transition. Leaders must be transparent with the stakeholders about the technology's intentions and its potential benefits. This approach can help build trust and facilitate collaboration, ensuring that the concerns and needs of all stakeholders are addressed. Leadership must also invest in reskilling to expand employment opportunities and reduce the fear of job loss, which can contribute to resistance.
- **Quote:** "*The way you overcome it [resistance] is to explain that what we're doing is to become more efficient. The reason why we are automating machines is to get more productive. When you automate machines, you can keep them working during normal times and when you wouldn't normally have people on underground, i.e., after a blast. Automation will make the mining process more efficient by reducing costs and making the mining industry more viable. This will lead to the increase in the profitable life of mine, and employment. The introduction of new technology can and will have the ability to have a positive impact on mining operations.*"
- **Quote:** "*No, you have to put a lot of effort through automation, create transferable skills that will be transferable elsewhere in the job space, in the world outside of mining, and you have to do so as an organization; create jobs much bigger and better to offset the impact of automation to such an extent that you almost first have to eradicate unemployment before you are successful with this [automation] I can see how you're going to get automation into mining environment and how you are going to exacerbate the issue of unemployment.*"

Leadership's Role in decision-making and consensus building

- **Theme 5:** Cross-functional Collaboration Encouraged by Ambidextrous Leaders
  - **Finding:** Employees frequently mention that ambidextrous leaders facilitate cross-functional collaboration, ensuring that stakeholders from different parts of the organization are involved in decisions related to technology adoption. This leadership style helps build consensus, especially in the decision-making phase.
- **Quote:** "*The first thing that leaders need to do is to develop the vision around this implementation. Then they need to engage with the stakeholders involved, the people that must implement this, such as original equipment manufacturers, suppliers of technology, the employees who develop the application process, etc. Leaders need to engage with all stakeholders to ensure that they are all on board. This is important so that they all can understand how they can contribute in delivering the outcome that leaders have articulated in their vision.*"

Balancing Exploration and Exploitation

- **Theme 6:** Dual Leadership Behaviours in Ambidextrous Leaders
  - **Finding:** Case studies and interviews reveal that ambidextrous leaders can switch between behaviors depending on the phase of the technology adoption process. During exploration, they exhibit transformational behaviours, fostering creativity and risk-taking. During exploitation, they shift toward transactional or servant leadership behaviours, focusing on execution, efficiency, and process optimization.
- **Quote:** "*On the level of flexibility in leadership; there is time to be flexible and there is time to be inflexible. In an idea generation stage, you must be at a five [out of five] but as you progress, evaluate until you come up with a proper concept, I mean once a concept is cast in stone I don't expect flexibility, otherwise you will never finish. Depending on where you are on the implementation of the innovation you start being flexible in the beginning. As you move towards finalizing the actual idea or the business case, the flexibility must come down to a three. However, you can never be inflexible because better ideas can come up during implementation so you should never get to a one flexibility. Lowest flexibility that can be achieved is a two because if an idea is proved to yield benefits the only difference is a new idea, which can yield more benefits, but it doesn't mean the original idea stops yielding benefits. At least capture the benefits that you started with, and you can take the new idea as an improvement on the original idea after the benefits of the original idea have been realised.*"

Cultural and Organizational Factors Influencing Leadership and Technology Adoption

- **Theme 7:** Organizational Culture as a Mediator
  - **Finding:** In some organizations, the existing culture either facilitates or hinders the success of leadership's efforts to adopt new technologies. Companies with cultures of openness and collaboration are more successful in adopting technologies when leadership behaviors align with these values. Additionally, the characteristics and readiness of the workforce to adopt new technologies must be carefully considered as a critical factor in the process.
- **Quote:** "*The involvement of leadership varies from company to company and the reason it varies from company to company is that the maturity of that specific company in terms of just technology in general. I have worked in companies where most of the people, in general, are relatively technology driven. They want to be on the leading edge. This is a general culture in the company of cutting edge, they want to be the first. In companies like that, technology is driven by people. They want to do that [innovate], they are kind of pushing the envelope all the time, but I've also seen companies where they are relatively immature in terms of what I've said and if this is the case, having the right leaders in place to push the technology agenda is extremely important.*"
- **Quote:** "*The younger generation tends to adopt new technologies more easily, especially when it comes to using smartphones. They quickly grasp the basics with minimal explanation and adapt swiftly. In contrast, the older generation often struggles with technology, requiring more extensive training, guidance, and support. When designing applications, it's important to keep them simple and user-friendly to prevent frustration, especially for older users. This highlights a generational difference, where younger individuals find technology adoption easier, while older individuals face more challenges.*"

Barriers to Technology Adoption

- **Theme 8:** Resistance to Change and Leadership Strategies
  - **Finding:** Resistance to change is a common barrier identified by participants. However, it can be noted that adaptive and transformational leaders are most effective at addressing this resistance, using communication, empathy, and vision to help employees understand the value of the new technology.
- **Quote:** "*The way you overcome it is to try to explain that what we're trying to do is become more efficient. Why we are automating machines is to try to get more work out of the machine. When you automate machines, you can keep them working during normal times and when you wouldn't normally have people on underground, i.e., after a blast, automation would make the mining process more efficient to reduce costs and the mining industry becomes more viable. Therefore, because you can reduce costs, you can keep some mines open that under normal working practices wouldn't be able to work. Therefore, more mines in operation safeguard employment rather than destroy it by introducing technology.*"
- **Quote:** "*To drive innovation within a company, it's essential to actively involve employees from the start. This can be done by organizing focus groups and brainstorming sessions, where employees across departments can share their work challenges and suggest how technology could improve their roles. This collaborative approach helps identify potential technologies and projects that align with business needs. Once a suitable technology is chosen, it's important to manage the change effectively. Early communication about the impact of the technology on employees' day-to-day tasks is crucial, along with*

providing necessary training. Throughout the implementation process, it's vital to keep all stakeholders informed of progress. This ongoing communication and support ensure that, by the time the project is complete, employees are ready to accept and adopt the new technology."

Outcomes of Technology Adoption Driven by Leadership

- **Theme 9:** Operational Efficiency
  - **Finding:** Participants describe how leadership, particularly transactional and servant leaders, ensures that new technologies are integrated efficiently, minimising disruptions to existing workflows.
- **Quote:** "*One of the key challenges when introducing new projects or trials is overcoming resistance from the workforce, such as operators or labourers. They can hinder or even sabotage the project, especially if they feel their jobs are at risk, regardless of whether the project might have succeeded otherwise. From a leadership perspective, this is particularly difficult. Large mining companies must ensure that mine management, supervisors, and all levels of leadership fully grasp the importance of their role in fostering innovation. If leadership focuses too heavily on controlling costs, as often reflected in KPIs, it becomes difficult to engage these teams in new initiatives. Employees may struggle to meet their KPIs, while also supporting innovation. Therefore, it's crucial for senior leadership to align incentives in a way that encourages innovation. A failure to do so has often been a barrier to progress in the industry*."

Discussion on objectives and ALTA Model

The findings from the interviews conducted, provided significant insights into how different leadership styles influence various stages of the technology adoption process within organizations, particularly in the mining industry. Transformational leaders play a crucial role in fostering innovation and encouraging risk-taking, while ambidextrous leaders are highly effective in balancing exploration (innovation) and exploitation (operational efficiency). Transactional and servant leaders are critical during the implementation and application phase, ensuring that technology is adopted efficiently. Ultimately, the findings suggest that leadership not only shapes the technology adoption process, but also directly influences the organization's innovation performance and operational efficiency.

The adoption of new technologies is highly dependent on the organizational culture, the flexibility of leadership, and the ability of leaders to foster collaboration and consensus-building among stakeholders. Leadership's role in addressing barriers such as resistance to change, structural limitations, and resource constraints is vital for the successful integration of innovative technologies.

This section discusses the findings in relation to the study's objectives and the ALTA model proposed earlier. The results are interpreted in the context of the literature and conceptual framework, addressing how leadership styles can influence technology adoption, innovation performance, and operational efficiency within organizations.

Leadership's role in fostering innovation

The findings reveal that transformational leadership is instrumental in the exploration phase of technology adoption. Leaders with transformational qualities—visionary, charismatic, and risk-taking—were found to create an environment where innovation could thrive.

This is consistent with the literature, which emphasizes that transformational leaders foster creativity and open-mindedness, key ingredients for breakthrough innovations (Bass, 1985).

However, the findings also suggest that innovation cannot occur in isolation from operational needs. Ambidextrous leadership was found to be crucial in balancing exploration with exploitation, ensuring that organizations do not over-prioritize experimentation at the expense of efficiency. This finding aligns with the work of O'Reilly and Tushman (2013), who highlight the importance of balancing exploration and exploitation to ensure the long-term success of an innovation.

Leadership's role in implementing technology

Transactional leadership was found to be essential in the exploitation phase of technology adoption. This leadership style focuses on clear goal setting, establishing timelines, and managing the process to ensure that new technologies are seamlessly integrated into the organization. The interviews suggest that without structured leadership during implementation, projects can face challenges such as disorganization or scope creep, confirming the need for strong transactional leadership to maintain operational focus (Burns, 1978).

The importance of adaptive leadership was also highlighted, especially in managing resistance to change. This finding is consistent with Heifetz's (1994) work, which emphasizes the need for leaders to guide organizations through periods of uncertainty and change by adapting to new circumstances and addressing employee concerns.

Overcoming barriers to technology adoption

The study identified several barriers to technology adoption, including resistance to change, and structural constraints. The study confirmed that organizational culture plays a critical role in determining the success of leadership efforts in technology adoption. Companies with cultures of collaboration and openness are likely to be more successful in adopting new technologies, which supports previous research that links organizational culture with innovation (Schein, 2010). Leaders in such environments can align their behaviors with the existing cultural values, facilitating smoother technology integration.

The role of cross-functional collaboration

Ambidextrous leadership also emerged as a facilitator of cross-functional collaboration, an important factor in technology adoption. Leaders who could effectively bring together diverse teams and encourage collaboration across departments are able to build consensus, especially in the decision-making phase. This is consistent with the findings of Raisch and Birkinshaw (2008), who argue that ambidextrous leaders play a key role in promoting collaboration and coordination within organizations, especially when adopting new technologies.

Leadership's impact on innovation performance and operational efficiency

The findings underscore the impact of ambidextrous and transformational leadership styles on innovation performance. Organizations led by these types of leaders are consistently at the forefront of innovation, introducing new products and processes faster than their competitors. This finding supports the broader literature, which emphasizes the role of transformational leaders in creating a culture of innovation and driving organizational change (Jung et al., 2003).

In contrast, operational efficiency was found to be heavily influenced by transactional and servant leadership styles. These leaders focus on ensuring that new technologies are integrated smoothly, without disrupting existing workflows, which is crucial for maintaining operational stability. The findings align with Burns' (1978) distinction between transformational and transactional leadership, where the latter is more focused on maintaining efficiency and achieving short-term goals.

Addressing the ALTA Model

The findings largely support the ambidextrous leadership-technology adoption (ALTA) model proposed in this study. The model's emphasis on balancing exploration and exploitation was confirmed by the participants, who consistently highlighted the need for leaders to foster innovation while maintaining operational focus. The dual behaviors exhibited by ambidextrous leaders—switching between transformational and transactional styles depending on the phase of technology adoption—were found to be particularly effective.

Conclusion

This study set out to explore the role of leadership in the technology adoption process, particularly within the context of mining organizations. The research focused on the integration of various leadership styles and their influence on fostering innovation, managing resistance, and ensuring efficient implementation. The development and testing of the ambidextrous leadership-technology doption (ALTA) model provided a framework for understanding how leaders can balance the dual demands of exploration (driving innovation) and exploitation (maintaining operational efficiency) in a complex and technology-driven environment. From the main aim of the study the relevance of the ambidextrous leadership-technology adoption (ALTA) model in addressing gaps in the direct role of leadership in technology adoption has been shown.

The findings from the qualitative interviews affirmed that leadership is an indispensable factor in the successful adoption of new technologies. Transformational leadership was identified as critical for inspiring innovation and encouraging risk-taking, while transactional leadership played a key role in ensuring that technology was integrated efficiently during the implementation phase. Moreover, ambidextrous leadership emerged as essential for balancing the need to explore new technologies while also ensuring that current operational processes are optimized.

What is further evident is that there is no one leadership style that will effectively deal with the successful adoption of new technology, but that the ALTA model points us in the right direction, which was also highlighted by participants in the survey conducted. One therefore needs to look at leadership actions and behaviors that will enhance or are needed in a successful approach towards new technology adoption.

The study also highlighted the importance of adaptive leadership, particularly in managing resistance to change, which is often a significant barrier to technology adoption. Leaders who demonstrated flexibility, empathy, and clear communication are better able to address concerns related to job security and other anxieties associated with technological disruption.

Organizational culture is revealed as a critical mediator in the relationship between leadership and technology adoption success. Companies with a culture of openness, collaboration, and innovation are more likely to succeed in adopting new technologies, as leadership behaviors aligned with these values facilitate smoother transitions.

Finally, the study demonstrates that leadership plays a pivotal role in driving technology adoption, fostering innovation, and managing the challenges associated with technological change. The ambidextrous leadership-technology adoption (ALTA) model provides a robust framework for understanding how leaders can navigate the complexities of technology adoption, balancing the need for exploration and exploitation, while addressing resistance and fostering a culture of collaboration and innovation. As industries continue to evolve in response to technological advancements, the role of leadership will remain critical in ensuring that organizations not only adopt new technologies but thrive in an increasingly digital future.

Contributions to knowledge

This study makes several important contributions to the field of leadership and technology adoption. First, it expands the understanding of ambidextrous leadership, providing empirical support for the ALTA model. The study demonstrates that ambidextrous leaders are uniquely positioned to switch between transformational and transactional leadership behaviors depending on the phase of the technology adoption process. Second, the study highlights the importance of adaptive leadership in overcoming resistance to change and addressing the human elements of technology adoption, particularly in industries facing rapid technological shifts, such as mining.

Additionally, the study provides practical insights for leaders in technology-intensive industries, offering strategies for balancing innovation with operational efficiency, managing cross-functional collaboration, and fostering a culture conducive to technology adoption.

While this study provides valuable insights, it is not without limitations. The research was primarily qualitative and focused on a specific industry (mining), which may limit the generalizability of the findings to other industries or contexts. Additionally, the study did not explore the long-term effects of leadership on technology adoption, which could be a potential avenue for future research. Further studies could quantitively validate and refine the ALTA model by applying the model in a real-life innovation project.

Recommendations

The study offers several practical recommendations for leaders in organizations adopting new technologies:

1. **Foster a culture of innovation:** leaders should actively promote a culture where innovation is encouraged at all levels of the organization. This includes creating environments where employees feel safe to propose new ideas and take calculated risks.
2. **Balance exploration and exploitation:** leaders must balance the pursuit of new technological innovations with the need to maintain and optimize existing processes. Ambidextrous leadership, which enables leaders to switch between exploratory and exploitative behaviors, is essential in achieving this balance.
3. **Manage resistance through communication and reskilling:** leaders must proactively manage resistance by clearly communicating the benefits of new technologies and offering reskilling opportunities for employees whose roles may be affected by automation or other technological advancements.
4. **Encourage cross-functional collaboration:** successful technology adoption requires leaders to facilitate collaboration between different departments and stakeholders, ensuring alignment across the organization.

Future research

Future research could also explore the role of emerging leadership styles, such as digital leadership, which may play an increasingly important role as industries continue to adopt advanced technologies, such as artificial intelligence and machine learning. The feedback on the literature, in some cases seems to be outdated, but is still applicable. We are in the cusp of the Fourth Industrial Revolution, which relates significantly to an escalated new technology availability and the related adoption challenges associated with it. New research relating to leadership and technology adoption will in future become even more relevant, including the subsequent research interventions related to it.

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