

Re-Envisioning Leadership Practice for an Uncertain Future: A Conceptual Synthesis Based on Critical Realist View and Quantum Principles

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Abstract

Existing leadership theories often fail to address the complexity and uncertainty of today's volatile environments, reducing leadership to fixed traits, prescriptive styles, or simple cause-and-effect models. This study challenges these paradigms by integrating critical realism with quantum principles, creating a framework that reflects the multifaceted demands of modern leadership. The proposed model views leadership as a multi-layered, adaptive process where past experiences, present conditions, and future possibilities interact continuously. By incorporating quantum concepts like superposition, entanglement, and subjective probabilities, this framework redefines leadership as dynamic and relational, enabling leaders to balance conflicting demands and adapt decisions in real time. This probabilistic approach shifts away from rigid, deterministic models, empowering leaders to operate with resilience in complex, ambiguous contexts. For research, this synthesis provides new opportunities to explore hidden social, psychological, and cultural mechanisms that shape leadership. Beyond observable metrics, it emphasizes the deeper forces underlying leadership dynamics, inviting interdisciplinary studies across physics, psychology, and organizational behavior. For practitioners, retroductive inference fosters an approach that integrates theoretical insights with practical tools, enabling leaders to uncover root causes, analyze patterns, and refine strategies through counterfactual thinking. By addressing underlying mechanisms rather than surface symptoms, it empowers leaders to make informed and decisive choices in complex, dynamic contexts.

Keywords

Leadership, Critical Realism, Quantum Principles, Retroductive Inference, Adaptive Decision-Making, VUCA

1. Introduction

Leadership in today's volatile, uncertain, complex, and ambiguous (VUCA) world demands frameworks that extend beyond traditional paradigms. Conventional leadership theories often emphasize traits, styles, or linear cause-and-effect relationships, failing to capture the complexity and interconnectedness of modern organizational challenges. This paper introduces a novel framework integrating critical realism and quantum principles to address these gaps, offering a dynamic, layered perspective on leadership.

Critical realism highlights the hidden mechanisms and unobservable structures that shape leadership phenomena, providing a multidimensional approach to analyzing social and organizational dynamics. Meanwhile, quantum concepts such as superposition, entanglement, and probabilistic decision-making align closely with the non-linear, adaptive requirements of contemporary leadership. These quantum principles enable leaders to hold multiple strategies simultaneously (superposition), acknowledge interdependencies within teams and systems (entanglement), and navigate ambiguity through probabilistic reasoning.

By synthesizing these approaches, the proposed framework redefines leadership as an adaptive, relational process influenced by past experiences, present dynamics, and future uncertainties. This synthesis directly addresses the limitations of traditional models by incorporating both the hidden structures emphasized by critical realism and the dynamic, probabilistic insights derived from quantum mechanics. The result is a cohesive theoretical foundation that equips leaders to balance conflicting demands, foster adaptability, and make informed decisions in complex, rapidly changing contexts.

Purpose and Rationale

Critical realism highlights the hidden mechanisms and unobservable structures that shape leadership phenomena, providing a multidimensional approach to analyzing social and organizational dynamics and Quantum-inspired concepts (Wendt, 2014; Bhaskar, 1975a). Critical realism emphasizes unobservable structures and causal mechanisms, such as power dynamics or cultural values, that underpin leadership actions, enabling leaders to address systemic challenges effectively, while quantum concepts introduce probabilistic and relational perspectives, offering a model that prepares leaders to manage ambiguity and adapt to continuous change.

Significance

By synthesizing these approaches, the proposed framework redefines leadership as an adaptive, relational process influenced by past experiences, present dynamics, and future uncertainties (Cropanzano, 2009). The mathematical study of psychological phenomena seeks to improve upon traditional, often ambiguous, verbal theorizing by creating precise models that describe, predict, and explain behavioral and cognitive processes. This approach enables differentiation between competing theories. Mathematical models range from descriptive, which captures observed data patterns, to explanatory, which outlines underlying processes. By

quantifying constructs, mathematical psychology brings clarity and predictive strength to psychological theories, enhancing the rigor and reliability of psychological research (Franco & Iglesias, 2023). Quantum concepts such as superposition, entanglement, and probabilistic decision-making align closely with the non-linear, adaptive requirements of contemporary leadership: superposition equips leaders to maintain flexibility across strategies, such as balancing immediate team needs with long-term innovation, until decisive action is required (Wu, Cormican, & Chen, 2020). These concepts offer both theoretical insights and practical applications that can enhance leaders' adaptability and effectiveness.

Research Objectives

1) Theoretical Integration: To unify fragmented research on leadership by combining critical realism and quantum perspectives, addressing limitations in traditional positivist models and providing a comprehensive view of leadership as shaped by both observable and hidden mechanisms.

2) Temporal Dimensions: To advance understanding of leadership by incorporating past, present, and future perspectives to show how leaders can leverage experience and current insights to shape future strategies.

3) Practical Applications: To leverage retroductive inference as a framework for uncovering root causes, refining strategies, and addressing underlying mechanisms, enabling leaders to make informed decisions in complex, dynamic contexts.

Study Framework

This paper presents a cohesive synthesis of quantum principles and critical realism to reconceptualize leadership. It begins with an introduction outlining the study's purpose and the need for a framework that transcends traditional leadership paradigms. The literature review then explores leadership paradigms and quantum concepts, identifying gaps in addressing modern organizational complexity. The methodology section explains the criteria and rationale for integrating quantum and realist perspectives. In the analysis, core quantum concepts like superposition and entanglement are synthesized with critical realist views, forming a novel framework that highlights leadership's dynamic and relational nature. The conclusion discusses theoretical contributions, practical implications, and future research directions, guiding the reader through the study's progression from foundational theory to integrative insights on adaptive leadership.

2. Literature Review

In this chapter, we explore the theoretical foundations that underpin the study, synthesizing diverse literature streams to build a comprehensive conceptual framework. The section begins with a review of key leadership theories that inform the study, drawing from established models and frameworks across critical realism, quantum Bayesianism, quantum social science, and adaptive leadership. Each literature stream is analyzed to extract fundamental principles and concepts, highlighting their interconnectedness to demonstrate how leaders can adaptively

manage diverse challenges such as team dynamics or organizational shifts. The synthesized concepts form the basis for the study's analysis, setting the stage for a novel theoretical integration that responds to complex, dynamic organizational contexts.

2.1. Leadership Understanding: An Evolved Overview

Leadership is a dynamic and multifaceted concept, commonly defined by scholars in terms of influence, goal alignment, and focus across temporal contexts. While [Kotter \(2012\)](#) emphasizes a visionary, forward-looking approach that aligns and inspires people to achieve a shared future, [Northouse \(2016\)](#) focuses on leadership as a relational process of influencing groups toward common goals in the present. Similarly, [Antonakis & Day \(2018\)](#) highlight leadership's impact on both individuals and institutions without a specific temporal focus, suggesting its role in shaping broader objectives. [Yukl \(2010\)](#), meanwhile, provides an action-oriented perspective, emphasizing the importance of both goal agreement and practical facilitation for achieving shared outcomes.

Each of these perspectives contributes to our foundational understanding of leadership but often overlooks the dynamic, complex, and interconnected nature of modern organizational environments. This paper's framework builds on these theories by integrating critical realism and quantum concepts, addressing the adaptability, uncertainty, and nuanced interdependencies that contemporary leaders face.

An essential aspect of leadership involves integrating perspectives from the past, present, and future to navigate complexities and uncertainties. The past offers a foundation of experiences and lessons, providing leaders with insights for current decision-making and strategic planning ([Beckert, 2013](#); [Vroom, Porter, & Lawler, 2015](#)). Drawing on past crises and institutional knowledge, leaders can leverage proven strategies and create a sense of continuity, fostering trust within their teams ([Ayman & Korabik, 2010](#); [Beckert, 2016](#)). In the present, leadership manifests through direct influence, guiding immediate actions and aligning team efforts to achieve shared objectives ([Benson et al., 2016](#)). This phase is where leaders exert the most visible impact, as present decisions shape both short- and long-term outcomes ([Wong & Kuvaas, 2018](#)).

Looking toward the future, leadership involves creating compelling visions, aligning with [Kotter's \(2012\)](#) notion of inspiring people toward a shared goal. Leaders construct "fictional expectations" about future opportunities to motivate and direct team efforts ([Beckert, 2013](#)). This future-oriented vision requires balancing past insights with speculative projections to anticipate potential challenges and guide the organization through uncertainty ([Tversky & Kahneman, 1992](#); [Foster & Frijters, 2014](#)). Thus, effective leadership constantly aligns past experiences with present influence and future-oriented expectations, creating a feedback loop that strengthens decision-making and strategic vision.

Leadership, Expectations, and Decision-Making

Leadership, expectations, and decision-making are interdependent and shape

organizational outcomes. Cultural, psychological, and ethical factors impact leaders' decision-making processes and set expectations within the organization (Bhugra & Gupta, 2010). Modern leadership models, such as Agile, Transformational, and Servant Leadership, each offer distinct approaches to guiding organizations. Agile Leadership emphasizes flexibility and quick responses to dynamic challenges, Transformational Leadership focuses on inspiring and aligning individuals with a shared vision, and Servant Leadership prioritizes ethical behavior and employee well-being, aligning well with collectivist cultures (Porkodi, 2024).

Adaptive Leadership further integrates these elements by focusing on iterative, context-sensitive responses to complex, evolving challenges. It encourages leaders to observe, interpret, and intervene continuously, balancing immediate actions with long-term goals and navigating uncertainty and ambiguity effectively (Heifetz, Grashow, & Linsky, 2009). Through this approach, leaders engage past experiences, present dynamics, and future possibilities to foster resilience and adaptability in their teams, essential qualities in complex environments (Kuntz et al., 2017; Dunn, 2020; Fausett et al., 2024).

These leadership models collectively address different dimensions of influence, from fostering rapid adaptation to building trust and social cohesion, ultimately enabling organizations to meet the demands of today's volatile, uncertain, complex, and ambiguous (VUCA) world.

2.2. Leadership Paradigms: Positivism, alternative Worldviews, and Critical Realism

Positivism, with its emphasis on empirical observation and quantitative methodologies, has been foundational in leadership research for its focus on objectivity and generalizability (Salloum et al., 2016; Bernerth et al., 2017; Bowers, 2017). However, its limitations emerge when addressing the complexity and context-dependent nature of leadership, as it often overlooks social constructs and hidden dynamics. Alternative paradigms such as interpretivism, constructivism, pragmatism, and systems theory offer broader frameworks, emphasizing context, interaction, and the relational aspects of leadership (Kempster & Parry, 2011; Fairhurst & Connaughton, 2014; Uhl-Bien & Marion, 2011).

2.2.1. Critical Realism in Leadership

Critical realism (CR) bridges positivism's strengths with an awareness of deeper, often unobservable mechanisms influencing leadership. Unlike traditional models, CR adopts a stratified understanding of reality, acknowledging that leadership emerges from the interaction of various layers of influence, beyond observable events (Bhaskar, 1975a; Krauter, 2020a). CR highlights not only behaviors but also the structural and causal forces that shape them, providing a more comprehensive analysis of leadership dynamics (Willis, 2019; Kempster & Parry, 2011).

Critical realism (CR) provides a nuanced framework for understanding leader-

ship by exploring both observable behaviors and hidden mechanisms. Unlike positivist models, CR emphasizes the layered reality of leadership, where interactions between visible events and underlying structures, such as power dynamics and organizational culture, shape leadership outcomes (Kempster & Parry, 2011). By investigating these hidden forces, CR uncovers how Leadership transcends individual actions, emphasizing the importance of systemic analysis and retroductive inference to uncover hidden barriers and align team efforts. Superposition allows leaders to balance potential strategies, while entanglement fosters interdependence in team goals, ensuring alignment in achieving complex organizational objectives by broader social, psychological, and organizational structures (Sayer, 2000; Krauter, 2020b).

CR operates within a stratified ontology of three domains: the empirical (observable events), the actual (events that may not be observed), and the real (causal mechanisms). This approach acknowledges that leadership arises from complex, interacting factors beyond surface behaviors, providing a holistic view of its development (Bhaskar, 1975a; Krauter, 2020b).

2.2.2. Four Planes of Social Being in Critical Realism

Roy Bhaskar's four-plane model explores leadership through interconnected levels:

1) Material Transactions with Nature: Leadership is affected by external conditions, such as VUCA (volatile, uncertain, complex, and ambiguous) environments, and workplace factors that influence organizational change and adaptability (Kotter, 2012; Krauter, 2018).

2) Interpersonal Relations: Social interactions between leaders and followers shape leadership through collaboration, shared decision-making, and motivation, which are essential for team cohesion (Lichtenstein & Plowman, 2009; Krauter, 2022).

3) Social Structures: Organizational systems, cultural norms, and power dynamics provide a framework within which leadership operates, impacting autonomy, competence, and overall leadership behavior (Northouse, 2018; Hofstede, 2001).

4) Personal Identity: Internal factors like self-efficacy, psychological capital, and emotional regulation influence leaders' abilities to adapt, make decisions, and respond to challenges (Bandura, 1997; Luthans, 2015; Krauter, 2019).

By integrating these planes, CR offers a comprehensive approach to leadership, enabling leaders to understand and address both immediate interactions and the systemic and personal factors that shape their roles in complex organizational settings (Bhaskar, 2009).

Table 1 summarizes key leadership factors across the four planes of social being—material transactions with nature, interpersonal relations, social structures, and personal identity—highlighting challenges leaders face in adapting to complex environments.

Table 1. Leadership factors across the four planes of social being.

Plane of Social Being	Influencing Factors	References
Plane of Material Transactions with Nature	VUCA Environments Volatility, uncertainty, complexity, and ambiguity (e.g., economic instability, geopolitical tensions).	Krauter (2018)
	Multi-Crisis Contexts External disruptions such as pandemics, climate change, and geopolitical crises.	Krauter (2023a); Gencer & Batirlik (2023)
	Organizational Change Changes driven by external factors like technological advancements, market disruptions, or economic downturns.	Kotter (2012)
	Workplace Conditions The material and organizational conditions affecting leadership behavior, such as decentralized decision-making and culture.	Krauter (2020b)
Plane of Interpersonal Relations	Contextual Conditions Situational factors that constrain or activate leadership, such as crises and industry conditions.	Vroom & Jago (2007)
	Social Interaction The dynamic exchange between leaders and followers that shapes leadership behaviors.	Lichtenstein & Plowman (2009)
	Leader and Follower Roles Evolving roles shaped by interpersonal expectations, norms, and interactional dynamics.	Krauter (2020b); Bindlish & Nandram (2018)
	Collaboration Collective agency where leaders and followers work together toward shared goals.	Krauter (2022); Kolfshoten (2007)
	Power with (Collaborative Agency) Shared decision-making and influence between leaders and followers.	Krauter (2020b); Salovaara & Bathurst (2018)
	Conflict Management How leaders manage interpersonal conflicts to maintain team cohesion and productivity.	Krauter (2022)
	Motivation and Emotional Experience Leaders' expressions of hope, pride, and inspiration, which influence team morale and motivation.	Krauter (2023b)
Plane of Social Structures	Shared Goals Common objectives that unite leaders and followers, fostering collaboration and motivation.	Bennis (2007)
	Trust and Influence Building interpersonal trust for effective leadership.	Dirks & Ferrin (2002)
	Collaborative Sensemaking The process by which leaders and their teams interpret complex or ambiguous situations.	Krauter (2018); Paul & Reddy (2010)
	Basic Psychological Needs (Relatedness) The need to feel connected and supported in relationships.	Ryan & Deci (2017)
	Institutional and Organizational Structures Formal systems and hierarchies that dictate how leadership is enacted.	Northouse (2018)
	Power over (Coercive Power) The exercise of hierarchical or authoritarian power, where leaders exert control.	Krauter (2020b); Salovaara & Bathurst (2018)

Continued

	Cultural Norms and Expectations Broader societal and organizational norms influencing leadership styles and behavior.	Hofstede (2001)
Plane of Social Structures	Role Ambiguity Structural uncertainty or lack of clarity around leadership roles.	Krauter (2020b); Biddle (1986); Stryker & Burke (2000)
	Workplace Structures Broader organizational systems like hierarchies and reporting lines.	Ghoshal & Bartlett (1994)
	Basic Psychological Needs (Autonomy and Competence) Supported or constrained by organizational structures.	Krauter (2023a); Ryan & Deci (2017)
	Self-Efficacy A leader's internal belief in their ability to lead effectively.	Bandura (1997)
Plane of Inner Being (Personal Identity)	Psychological Capital Internal resources like hope, optimism, and resilience.	Krauter (2019); Luthans (2015)
	Personal Power Leaders' personality can be a source of personal power, such as an expert or referent position.	Lunenburg (2012); Ojo et al. (2016)
	Emotional Regulation Leaders' ability to manage their own emotions and others' emotions.	Krauter (2023a); Torrence & Connelly (2019)
	Autonomy Internal sense of control over decisions and actions, influencing leadership motivation.	Ryan & Deci (2017)
	Adaptive Performance The ability to adjust behavior and strategies in response to new challenges.	Krauter (2019); Tucker & Gunther (2009)
	Reflection and Sensemaking Cognitive processes by which leaders interpret complex or ambiguous situations.	Krauter (2018); Weick, Sutcliffe & Obstfeld (2005)
	Cognitive Processes Internal mechanisms like decision-making, strategic thinking, and problem-solving.	Mumford et al. (2000)
	Intrinsic and Extrinsic Motivation Leadership driven by internal growth or external rewards.	Krauter (2023b); Paumier & Chanal (2022)

2.2.3. Retroductive Theorizing in Critical Realism

Retroductive theorizing is an alternative approach to inductive or deductive inference for developing explanatory theories that elucidate complex causal mechanisms, particularly within the realm of leadership research (John, 2017; Kempster & Parry, 2011; Krauter, 2020b). Mukumbang et al. (2023) underscore retroductive theorizing's role in bridging qualitative insights and quantitative rigor, facilitating a systematic investigation of underlying mechanisms that connect leadership interventions with specific outcomes. This process, as guided by critical realism,

transcends mere empirical description by seeking causal relationships that explain observed phenomena, especially within the multifaceted contexts of leadership (Mukumbang et al., 2023). Willis (2019) presents retroduction as a critical realist approach to leadership learning, enabling deeper insight into hidden causal mechanisms by fostering iterative questioning and reflexive analysis of underlying leadership dynamics. Building on this foundation, Mukumbang, Kabongo, and Eastwood (2021) emphasize retroductive theorizing as essential for iteratively refining theoretical models.

To operationalize retroductive theorizing in leadership studies, the ICAMO model offers a structured framework that aids in dissecting and analyzing leadership phenomena. This model, as described by Mukumbang, De Souza, and Eastwood (2023), aligns with critical realism's objective to capture the layered nature of causality by breaking down complex social processes into actionable components: interventions reflect leadership strategies, contexts consider situational influences, actors refer to individuals involved, mechanisms highlight the driving processes, and outcomes denote the observable effects. The step-by-step application begins with identifying a leadership phenomenon or challenge—often sparked by inconsistent patterns—followed by selecting and analyzing extreme cases that exemplify unique ICAMO configurations. This approach, as Mukumbang et al. (2023) demonstrates theory building by pinpointing how contextual variations impact outcomes and reveal deeper mechanisms.

Key to retroductive theorizing is the use of counterfactual thinking, as posited by Vincent and O'Mahoney (2018). Through “what if” questions, researchers explore alternative scenarios within the ICAMO structure to identify crucial mechanisms or missing factors that clarify causality, offering insights into leadership dynamics that may otherwise remain obscured. Fletcher (2017) advocates abductive reasoning in this context to generate hypotheses that link interventions to specific outcomes, incorporating the entire ICAMO structure. Iterative testing across cases further solidifies these insights, as consistent ICAMO configurations reveal demi-regularities—patterns that appear stable yet adaptable across contexts, enabling robust cross-case analysis (Mukumbang, De Souza, & Eastwood, 2023).

Ultimately, synthesizing these retroductive insights into a practical theoretical model aids in illustrating effective leadership strategies. Such models, informed by continuous ICAMO-based testing and cross-context application, reflect Bhaskar's “reflect reality” principle by remaining adaptable for real-world application across various sectors (Mukumbang, De Souza, & Eastwood, 2023). This alignment of theoretical rigor with practical applicability underscores the unique contributions of retroductive theorizing to leadership studies, fostering a nuanced understanding that not only clarifies causality but also enhances the methodological robustness of critical realism in social science research.

Table 2 summarizes the process of retroductive theorizing in leadership, integrating insights and applications.

Table 2. Process of retroductive theorizing.

Step	Description	Key Actions	Supporting Research
1) Identify Leadership Phenomenon or Challenge	Begin by observing inconsistencies or noteworthy patterns in leadership behavior that require explanation.	Use the ICAMO framework to break down the phenomenon into components: Intervention (I), Context (C), Actors (A), Mechanisms (M), and Outcomes (O).	Mukumbang et al. (2023); Mukumbang, Kabongo, & Eastwood (2021)
2) Select and Analyze Extreme Cases with ICAMO Configurations	Examine typical, deviant, and crucial cases that show variations in leadership outcomes to identify unique ICAMO configurations.	Map out ICAMO for each case to capture specific interactions and contextual impacts on outcomes.	Mukumbang, De Souza, & Eastwood (2023)
3) Use Counterfactual Thinking	Pose “what if” questions to explore how alternative scenarios might influence outcomes within the ICAMO structure.	Identify essential or missing mechanisms by altering ICAMO components and assessing hypothetical changes.	Vincent & O’Mahoney (2018)
4) Apply Abductive Reasoning	Develop hypotheses linking interventions to outcomes, considering the role of each ICAMO component.	Generate explanations by testing theories about how specific interventions lead to outcomes in given contexts.	Fletcher (2017)
5) Conduct Iterative Testing Across Cases	Test ICAMO configurations across multiple cases to find stable yet adaptable patterns (demi-regularities).	Use cross-case analysis to identify recurring mechanisms and adjust ICAMO mappings for each new case.	
6) Synthesize into a Practical Model	Integrate insights into a theoretical model that reflects effective leadership strategies for diverse contexts.	Develop a context-sensitive model grounded in ICAMO that aligns with Bhaskar’s “reflect reality” principle.	Mukumbang, De Souza, & Eastwood (2023)

This structured approach using ICAMO components enhances theory building by exploring causal mechanisms in leadership contexts and ensures the final model is both theoretically sound and practically applicable across various organizational settings.

2.2.4. Summary of Leadership Paradigms

Table 3 shows the results of the consolidation of the core distinctions between positivist and critical realism/quantum mechanics paradigms in leadership studies. This summary highlights how the paradigms differ fundamentally in their approach to understanding leadership dynamics, addressing complexity, and applying theoretical frameworks to practice. The following table provides a detailed comparison of key factors, emphasizing critical aspects such as ontology, epistemology, social aspects, and adaptability frameworks.

Table 3. Key paradigmatic differences.

Key Factor	Positivist Leadership Paradigm	Critical Realism/Quantum Mechanics Paradigm
1) Ontology	Assumes a single, objective reality that leaders can fully understand and control.	Recognizes a stratified reality (empirical, actual, real) where hidden mechanisms and systemic dynamics shape observable outcomes.
2) Epistemology	Knowledge is derived from measurable, observable phenomena and empirical evidence.	Combines empirical observation with retroductive reasoning to uncover causal mechanisms and systemic interdependencies.
3) Nature of Leadership	Leadership is a linear process with cause-and-effect relationships between actions and outcomes.	Leadership is emergent, non-linear, and influenced by interdependencies, systemic dynamics, and quantum principles.
4) Social Aspects	Focuses on individual leaders and their traits, often isolating leadership from broader social dynamics.	Emphasizes relational and social entanglement, where leadership emerges through networks of influence and interconnected roles.
5) Context Dependency	Leadership principles are universal and assumed to work across all contexts regardless of specific environmental factors.	Leadership is highly context-dependent, shaped by systemic factors, relational dynamics, and contextual uncertainties.
6) Expectation	Assumes leaders can predict outcomes with certainty if the right processes and data are used.	Leadership operates within probabilistic frameworks, where expectations are managed through adaptive strategies and scenario planning.
7) Time	Leadership decisions are framed within linear timelines and focus on immediate results.	Time is treated as dynamic, with decisions balancing short-term actions and long-term systemic impacts in evolving environments.
8) Psychology	Views individuals as rational actors with predictable responses to incentives.	Considers psychological states as dynamic and probabilistic, influenced by relational, emotional, and systemic interactions.
9) Complexity	Reduces complexity into isolated parts for sequential problem-solving.	Addresses complexity holistically, treating it as emergent and systemic, with interdependencies resolved through quantum principles like interference.
10) Change Management	Reactive and symptom-focused, using step-by-step processes to manage visible organizational challenges.	Proactively addresses hidden causes of organizational issues using retroductive inference and anticipatory strategies.
11) Research Approach	Relies on universal laws and generalizable principles to explain and predict leadership phenomena.	Blends critical realism with quantum mechanics, recognizing multiple perspectives and layered realities in organizational behavior.
12) Framework for Adaptability	Adapts leadership through predefined styles and static traits.	Models adaptability dynamically, with flexibility emerging from superposition, entanglement, and systemic insights.

This comparative framework emphasizes the paradigm shift required to address modern leadership challenges in dynamic, uncertain environments. By transitioning from rigid positivist principles to more flexible and holistic approaches, leaders can develop adaptive strategies that align with the complexities of contemporary organizational settings.

2.3. Quantum Concepts

2.3.1. QBism—Quantum Bayesianism

QBism, or Quantum Bayesianism, offers a distinct interpretation of quantum mechanics by emphasizing the agent's active role in quantum processes. In QBism, quantum states are seen not as objective realities but as subjective judgments, capturing each agent's personal beliefs about possible outcomes. Fuchs (2023) outlines QBism's key tenets, focusing on how quantum formalism serves as a normative decision-making tool rather than a purely descriptive model. This agent-centered perspective shifts the focus of quantum mechanics from external reality to the agent's interactions, highlighting quantum mechanics as a framework centered on actions, consequences, and expectations deeply intertwined with Bayesian probability (Fuchs, Mermin, & Schack, 2014).

Aligning with philosophical traditions such as pragmatism and pluralism, QBism challenges the notion of objectivity, presenting quantum measurement devices as extensions of the agent's sensory experience. This view links quantum states directly to an agent's expectations of future events (Fuchs & Stacey, 2019; Pienaar, 2020). Through this perspective, QBism bridges the subjective experience of the agent with broader reality, offering a pragmatic approach to quantum mechanics that redefines the understanding of objectivity (Khrennikov, 2016).

In QBism, quantum states serve as subjective expressions of the agent's beliefs about future outcomes, with probabilities representing the agent's personal expectations based on prior experience (Fuchs, 2023). Rather than describing absolute truths, these probabilities express each agent's view of potential outcomes. This Bayesian framework aligns with the idea that quantum theory is fundamentally normative, designed to help agents refine probabilistic expectations, thereby shifting quantum states from fixed entities to expressions of belief (Fuchs & Stacey, 2019; Pienaar, 2020).

Central to QBism is the Born rule, which acts as a bridge between an agent's beliefs and the probabilities they assign to quantum outcomes. Unlike traditional interpretations, which regard the Born rule as reflecting objective properties, QBism views it as a normative tool guiding agents in refining their expectations through interaction with the quantum world (Fuchs, Mermin, & Schack, 2014). In this way, the Born rule constrains subjective probabilities, serving as a prescriptive method for managing uncertainty rather than a law describing physical properties (Pienaar, 2020; Khrennikov, 2016).

Another key element in QBism is Bayesian updating, which reinterprets the "collapse of the wave function" as a process of belief revision based on new meas-

urements (Fuchs, Mermin, & Schack, 2014). This process underscores QBism's commitment to personalism, where updating does not imply an objective collapse but rather reflects the agent's evolving understanding of quantum interactions (Pienaar, 2020). This updating process is free from traditional interpretations and reinforces the agent-centered focus of QBism (Khrennikov, 2016).

In QBism, quantum interference is not viewed as a physical phenomenon but rather as a consequence of the agent's subjective probabilities concerning potential outcomes. According to Fuchs (2023), interference arises from the agent's experiences and expectations rather than external reality, indicating that measurements reflect the agent's interaction with the system rather than revealing pre-existing outcomes (Fuchs, Mermin, & Schack, 2014; Pienaar, 2020). This interpretation diverges from traditional views by presenting interference as a reflection of the agent's probabilistic framework (Timpson, 2008; Khrennikov, 2016).

Finally, expectation values in QBism represent the agent's personal degrees of belief regarding future quantum events. These values are tied to the agent's interaction with the quantum system, where the agent's beliefs actively influence outcomes. In contrast to traditional interpretations that view expectation values as fixed properties of a system, QBism treats these values as subjective bets, reinforcing its emphasis on agency and action (Fuchs, Mermin, & Schack, 2014; Pienaar, 2020). This view of expectation values as subjective judgments reflects the broader QBist perspective, where the agent's choices and decisions shape their unique quantum reality (Fuchs & Stacey, 2019).

2.3.2. Quantum Social Science (QSS)

Quantum Social Science (QSS) introduces a new approach to modeling social interactions by drawing on the mathematical principles of quantum mechanics. Unlike traditional approaches, QSS does not assume that social systems are inherently quantum but uses quantum formalism to better capture the complexity and unpredictability of human behavior. Quantum mechanics' probabilistic structures offer a fitting analogy for the uncertainties and complexities in social systems, where human interactions and behaviors often resist simple, deterministic explanations (Haven & Khrennikov, 2013).

Wendt (2014) extends QSS by showing how the interconnected nature of social behavior—especially in language, cooperation, and culture—mirrors quantum entanglement. In his view, language functions as a type of “social entanglement” that allows individuals to connect and interact across various social and cultural boundaries. Similarly, Wayne (2014) argues that QSS applies quantum principles to address the probabilistic and interconnected nature of leadership, equipping leaders with tools to manage ambiguity and complexity in environments like VUCA (Volatile, Uncertain, Complex, Ambiguous) contexts. This approach allows for a more nuanced understanding of human decision-making and social interactions, bridging the natural and social sciences to create a cohesive explanatory model (Wendt, 2014; Höne, 2017).

In QSS, quantum states are interpreted as subjective probabilities, representing the beliefs, expectations, and uncertainties of individuals within a social context. This interpretation aligns with decision theory, where human decisions and perceptions exist in probabilistic states until a choice or observation “collapses” them into specific outcomes (Haven & Khrennikov, 2013). Wayne (2014) expands this idea, arguing that by combining quantum physics with psychology, QSS can address the “psychohistory paradox” in social science, integrating subjective probabilities with statistical methods.

A fundamental concept in QSS, as in quantum mechanics, is superposition. In social contexts, superposition suggests that individuals or agents can exist in multiple potential states or decisions simultaneously, each associated with a certain probability. Only through observation or decision-making does one specific outcome materialize, causing one state to collapse into reality (Haven & Khrennikov, 2013). Wendt (2014) describes how individuals can hold conflicting beliefs or potential actions simultaneously, an idea that captures the complexity and ambiguity of social behavior.

Entanglement in QSS models the interconnectedness of social agents, where the actions or decisions of one individual are inherently connected to others, even across distances. This concept explains how ideas and behaviors can spread through social networks, demonstrating that social roles and interactions are deeply interdependent, much like entangled particles in quantum mechanics (Haven & Khrennikov, 2013; Wendt, 2014). Wendt illustrates this by showing how relationships, like that of master and servant, are mutually defining and cannot exist independently, embodying the principles of quantum entanglement in social structures.

Quantum interference in QSS models the way possible social outcomes can influence each other, much like wave interference in quantum mechanics. This interference highlights how multiple options or paths can shape decision-making by interacting in a complex, probabilistic manner (Haven & Khrennikov, 2013). Wendt (2014) explains that quantum decision theory captures this dynamic interaction, which accounts for the often “irrational” patterns in human choices, as options are influenced by the overlap of multiple outcomes.

The concept of the density matrix in quantum mechanics, used to describe mixed states that exist as probabilistic mixtures, is adapted in QSS to model social systems where agents hold diverse or even conflicting perspectives. This approach is useful in understanding complex social groups and their decision-making processes, where individuals often operate within a matrix of competing beliefs and strategies (Haven & Khrennikov, 2013; Höne, 2017).

In QSS, the Born rule, which calculates the probability of specific outcomes based on quantum amplitudes, is used to predict the likelihood of different social behaviors and decisions. This application refines traditional probabilistic models, offering a structured way to assess probabilities in dynamic social systems, where classical probabilistic approaches may fall short (Haven & Khrennikov, 2013;

Höne, 2017). Through these principles, QSS provides a powerful framework for capturing the nuanced, probabilistic nature of human interactions within complex social networks.

Table 4 summarizes the key concepts of QBism (Quantum Bayesianism) and Quantum Social Science (QSS).

Table 4. Process of retroductive theorizing.

Concepts	QBism (Quantum Bayesianism)	Quantum Social Science (QSS)
Agent-Centric Focus	QBism posits that quantum states represent personal judgments, not objective realities, centering on the agent's role in measurement. Quantum states act as decision-making tools reflecting an agent's expectations (Fuchs & Schack, 2013).	QSS applies quantum mechanics' structures to social behavior, viewing social phenomena through a quantum lens. It models complex, interconnected human interactions with probabilistic frameworks that mirror uncertainties in human decision-making (Haven & Khrennikov, 2013).
Quantum States & Subjective Probabilities	In QBism, quantum states reflect the agent's subjective beliefs, not objective system properties. Probabilities express personal expectations, aligning with Bayesian principles where quantum states quantify belief rather than reality (Fuchs, 2023).	QSS interprets quantum states as subjective probabilities reflecting agents' expectations and uncertainties. Decisions and perceptions exist in probabilistic states that solidify into outcomes upon observation or decision-making (Wayne, 2014).
Born Rule	The Born rule is a normative tool in QBism, guiding agents in setting probabilities for outcomes. Rather than describing physical properties, it prescribes how agents should adjust beliefs based on interactions (Fuchs & Stacey, 2019).	QSS applies the Born rule to estimate probabilities in social systems, where the likelihood of various behaviors or decisions is calculated in dynamic social contexts (Haven & Khrennikov, 2013).
Bayesian Updating	Bayesian updating in QBism reinterprets wave function collapse as an update in the agent's beliefs after measurement, without implying an objective reality shift. This personalist view aligns updates with new data rather than an ontological change (Fuchs & Schack, 2013).	
Quantum Interference	In QBism, interference results from an agent's subjective probability assessments regarding outcomes. It reflects personal expectations rather than a physical interaction, emphasizing that measurements don't reveal objective reality but capture the agent's experience (Pienaar, 2020).	In QSS, interference models how potential decisions affect each other in human behavior, with competing options impacting final choices. This perspective aids in explaining seemingly irrational or complex behaviors in social decision-making (Wendt, 2014).
Expectation Values	Expectation values in QBism represent an agent's beliefs about future outcomes, emphasizing subjective readiness to act on anticipated results. These values reflect a probabilistic view where outcomes depend on the agent's beliefs (Fuchs, 2023).	Expectation values in QSS are applied to social predictions, with agents forming expectations about future events based on subjective, probabilistic assessments, which shape social actions and interactions.

Continued

Superposition	Superposition in QSS suggests agents can exist in multiple potential states, holding contradictory or uncertain beliefs until an observation or decision collapses one state into reality. This helps model the coexistence of social attitudes or states (Gerardi, 2018; Wendt, 2014).
Entanglement	Entanglement in QSS models the interconnectedness of social agents, where one agent's state or action directly affects others. This explains the spread of ideas or behaviors in social networks, where roles and interactions become inseparable (Wendt, 2014).
Density Matrix for Mixed States	The density matrix represents the mixed, probabilistic nature of social groups, where agents hold diverse or conflicting perspectives. It captures the complexity of group decision-making in QSS (Haven & Khrennikov, 2013).

The table above provides an overview of key concepts from QBism and Quantum Social Science (QSS), outlining how quantum principles can be applied to model social dynamics and subjective agency in complex environments. In the following section, we examine studies that demonstrate thematic parallels between these quantum concepts and real-world leadership contexts. By aligning leadership topics such as shared leadership, agility, and decision-making with quantum principles like entanglement, superposition, and interference, this exploration shows how the abstract themes of quantum mechanics can be effectively applied to leadership. The goal is to illustrate how these quantum-derived insights can enhance our understanding of leadership practices within VUCA environments.

2.3.3. The Appropriateness of Quantum Mechanics in Leadership

Quantum mechanics offers a compelling framework for understanding complex, interdependent, and uncertain phenomena within leadership, management, decision-making, and organizational theory. Its principles of superposition, entanglement, and indeterminacy provide insights that challenge and enhance traditional models. Busemeyer (2012) underscores quantum mechanics' role in decision-making by demonstrating how quantum interference effects can explain certain choice behaviors that classical decision theories cannot, enabling a nuanced view of human decision-making under uncertainty. Similarly, Agrawal and Sharda (2013) illustrate how quantum models in decision-making accommodate behaviors unaccounted for by classical models, such as the disjunction effect, showing that quantum concepts like interference can elucidate complex economic decisions.

In management, the quantum framework supports the concept of sustainable organizing, where interconnectedness and indeterminacy, akin to quantum entanglement, shape organizational structures (Dyck & Greidanus, 2017). This idea repositions firms within broader social and environmental contexts, aligning managerial actions with sustainability principles that transcend individualistic competitiveness. Knight & Hahn (2021) further explore organizational paradoxes using a quantum ontology, illustrating how paradoxes are not just inherent but also socially constructed, reflecting an ongoing duality that a classical framework would struggle to address. This quantum perspective enables a flexible, adaptive approach to organizational complexity, accommodating the persistent and dynamic nature of paradoxes.

The integration of quantum mechanics also provides novel insights into organizational change and time, where change is viewed as probabilistic rather than linear, aligning with quantum ideas of potentiality and collapse (Lord et al., 2015). By treating time as a state of potentiality, organizations can better respond to unforeseen events, fostering resilience in the face of uncertainty. Overman (1996) emphasizes that management practices rooted in quantum and chaos theories offer an advantage in addressing the unpredictable interdependencies within organizational systems. Baets (2007) reinforces this by suggesting that organizations operate as complex adaptive systems, where quantum principles like uncertainty and interconnectedness foster continuous learning and adaptation.

Moreover, quantum mechanics' implications for leadership and innovation are profound. Wells (2009) suggests that quantum-inspired leadership in professional learning communities harnesses entangled relationships and probabilistic dynamics, cultivating adaptive, interconnected teams. Zhao et al. (2022) apply quantum mechanics to promote knowledge-based innovation, portraying knowledge exchange as a dynamic, interdependent process that parallels quantum interactions. Quantum metaphors, however, demand careful contextual application, as Clark and Hunt (2024) caution against oversimplifying or misinterpreting these complex ideas within organizational studies. Nonetheless, the inherent unpredictability and non-linearity of quantum mechanics align with modern organizational needs, bridging gaps that classical models leave unresolved (Giacomuzzi, 2020; White et al., 2015).

Quantum concepts and leadership

Entanglement in quantum mechanics describes how the state of one particle can instantaneously influence another, regardless of distance, reflecting a form of interconnectedness that is also seen in shared leadership models. In this context, the actions of one team member directly impact others, creating a collaborative and interdependent structure. Wu, Cormican, and Chen (2020) illustrate how shared leadership thrives in complex environments by leveraging diverse perspectives and fostering a collective responsibility akin to quantum entanglement. This interdependent structure enables quicker adaptation and resilience, which is crucial in VUCA settings where collective action mitigates unpredictability.

Similarly, superposition in quantum mechanics allows a system to be in multiple states simultaneously, which parallels the agility leaders need in VUCA environments. Leaders often balance between immediate operational demands and future-oriented innovation. [Rimita \(2019\)](#) explores how leaders embody this ambidextrous approach, remaining prepared for multiple outcomes and dynamically adjusting strategies. Existing in a “superposition” of potential leadership stances allows leaders the flexibility to pivot as conditions evolve, reflecting an ability to navigate multiple possible futures.

Quantum interference, which occurs when overlapping waves create amplified or neutralized outcomes, serves as an analogy for crisis decision-making. In crises, leaders face a mix of psychological, emotional, and situational factors that can either support or hinder effective responses. [Richardson \(2024\)](#) suggests that leaders who harmonize these competing inputs—through trust, communication, and teamwork—achieve constructive outcomes. The concept of interference thus underscores the impact of synergy (or its absence) on crisis resolution, emphasizing the importance of aligning team dynamics to respond effectively in challenging times.

In quantum mechanics, mixed states capture a blend of multiple possible conditions, introducing inherent uncertainty, a concept applicable to organizational ambidexterity. Leaders practicing ambidexterity balance stability with change, operational efficiency with innovation. [Hossain, Kumar, Islam, and Valeri \(2024\)](#) describe this approach as navigating contradictory demands, managing immediate priorities while remaining open to future possibilities. Leaders effectively operate in “mixed states,” shifting between competing objectives in uncertain environments, essential in VUCA contexts where constant recalibration is key.

The density matrix in quantum mechanics encapsulates a system’s statistical state, encompassing both pure and mixed states. In leadership, this can be likened to strategic flexibility, where leaders maintain a range of responses for various scenarios. [Abe and Kang \(2023\)](#) explain that a leader’s strategic density matrix allows for quick shifts among strategies, enhancing adaptability. This flexibility is crucial in unpredictable environments, where leaders must prepare for multiple potential outcomes and pivot seamlessly as conditions change.

Finally, the Born rule in quantum mechanics, which calculates the probability of a system being in a particular state, finds a parallel in probabilistic decision-making under uncertainty. [Widiana and Soetjipto \(2021\)](#) emphasize the need for leaders to assess the likelihood of outcomes based on limited information, mirroring the probabilistic nature of the Born rule. This approach is essential for navigating VUCA environments, where leaders must rely on intuition, experience, and incomplete data to make informed decisions, adapting in real time to shifting circumstances.

2.3.4. Conceptual Framework of Emerging Leadership Phenomena

This framework, as visualized in [Figure 1](#), illustrates the interconnected layers and principles shaping the emergence of leadership phenomena. The figure integrates

the key elements of Critical Realism (CR) and Quantum Mechanics (QM) into a coherent structure, highlighting the dynamic interplay between these paradigms. It captures how leadership operates across the stratified reality levels (empirical, actual, and real), represented visually alongside the four planes of social being: material, interpersonal, social, and personal.

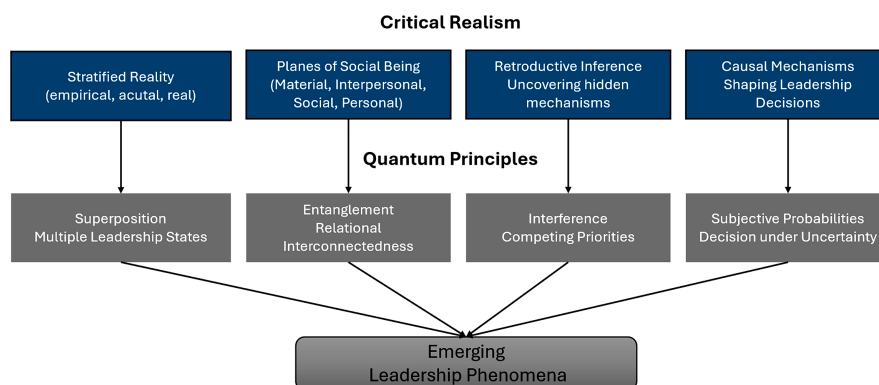


Figure 1. Emerging leadership phenomena—integrating critical realism and quantum principles.

The framework also depicts the probabilistic and interconnected aspects of Quantum Mechanics, including superposition (multiple leadership states), entanglement (relational interconnectedness), and interference (competing priorities), all of which influence leadership outcomes. These concepts align with CR's focus on uncovering hidden mechanisms through retroductive inference and understanding how causal forces shape leadership decisions.

The figure visually maps the connections between these elements, demonstrating how stratified reality intersects with entanglement, planes of social being correspond to superposition, and causal mechanisms interact with interference. This visual representation emphasizes the unified framework's capacity to address leadership's complexity, interdependence, and uncertainty.

By synthesizing these perspectives, **Figure 1** serves as a roadmap for navigating leadership challenges, visually reinforcing the theoretical underpinnings and practical applications. It underscores the dynamic, multi-layered nature of leadership and provides a clear framework for analyzing and adapting to evolving leadership contexts.

3. Methodology for Conceptual Synthesis

The applied methodology consists of a conceptual and theoretical synthesis aimed at advancing the understanding of leadership through the creation of a framework that integrates multiple theories. This approach transcends traditional literature review by not only summarizing existing knowledge but also reframing ambiguous areas, connecting previously unlinked ideas, and challenging established assumptions, thus providing enriched academic insight into leadership (Corley & Gioia, 2011). By integrating fragmented research into a cohesive, higher-order

perspective, this methodology enhances coherence across previously disparate studies in critical realism, quantum social science (QSS), and Quantum Bayesianism (QBism) within the field of leadership (MacInnis, 2011). The theoretical synthesis organizes key concepts and frameworks to form a comprehensive approach to analyzing leadership's complex nature and dynamics.

3.1. Critical Realism as Foundation

At the foundation of this approach is critical realism, which provides a nuanced ontological basis for understanding leadership. Within critical realism's layered view of reality, leadership is seen not merely as a set of observable actions but as a phenomenon deeply rooted in underlying structures and mechanisms that drive behaviors and outcomes (Bhaskar, 1975a). This multi-layered perspective distinguishes between the empirical (observable events), the actual (events that may go unobserved), and the real (causal mechanisms). Through this lens, the framework is equipped to explore the complexities of leadership beyond surface-level observations, offering a more comprehensive understanding of leadership as a dynamic and multifaceted process embedded in various levels of reality (Krauter, 2020b; Sayer, 2000).

Expanding on this critical realist foundation, the framework incorporates Roy Bhaskar's concept of the four planes of social being to structure the social reality of leadership. These planes represent distinct but interrelated levels of social existence that together influence leadership dynamics. The plane of material transactions with nature encompasses external material factors, such as economic forces, technological developments, and environmental challenges, which shape organizational contexts and the conditions under which leaders operate (Bhaskar, 2009; Kotter, 2012; Krauter, 2018). The plane of interpersonal relations focuses on social interactions between leaders and followers, emphasizing how relationships, collaboration, and team dynamics contribute to effective leadership (Lichtenstein & Plowman, 2009; Krauter, 2022). The plane of social structures encompasses institutional norms, organizational systems, and cultural frameworks that form the structural context within which leadership behaviors are enacted and influenced (Hofstede, 2001; Northouse, 2018). Finally, the plane of inner being, or personal identity, represents internal factors like self-efficacy, emotional resilience, and psychological capital, which significantly shape a leader's decision-making and adaptability (Bandura, 1997; Luthans, 2015; Krauter, 2019). By delineating leadership across these four planes, the framework situates it within a structured social reality that captures both its external and internal dimensions, allowing for a comprehensive examination of the interplay between individual agency and structural constraints.

Building on this ontological structure, the methodology employs retroductive inference to uncover the underlying mechanisms and configurations that enable leadership to manifest. Retroduction, a key reasoning approach in critical realism, enables the identification of causal mechanisms from observed outcomes (Mukumbang,

Kabongo, & Eastwood, 2021). In this framework, retroductive inference is enhanced by the application of quantum concepts—specifically, Quantum Bayesianism (QBism) and Quantum Social Science (QSS)—which support counterfactual thinking within the retroductive process. Counterfactual thinking is essential for exploring alternative scenarios and probing how different causal factors might interact to produce various outcomes. By envisioning “what if” scenarios, counterfactual thinking allows researchers to question and isolate critical mechanisms within the ICAMO configuration, identifying potential causal paths that may otherwise remain hidden.

These quantum concepts provide tools to model the probabilistic, relational aspects of leadership, enabling a structured exploration of how certain configurations of leadership factors might differ under alternate conditions. QBism offers an agent-centered perspective, where leadership decisions and outcomes are framed as subjective, probabilistic beliefs based on leaders’ personal expectations and past experiences (Fuchs, Mermin, & Schack, 2014; Fuchs & Stacey, 2019). This aligns with the view of leadership as a highly individualized, context-sensitive phenomenon. QSS applies quantum principles to social interactions, using concepts like entanglement and superposition to capture the interconnected and sometimes ambiguous relationships within leadership contexts (Wendt, 2014; Haven & Khrennikov, 2013). Together, QBism and QSS deepen the retroductive process by allowing complex, non-linear, and interdependent leadership dynamics to be explored from a probabilistic and relational perspective, directly informing counterfactual scenarios and enriching the counterfactual analysis.

The ICAMO model (Intervention, Context, Actors, Mechanisms, and Outcomes) is employed as the framework’s descriptive model to represent leadership configurations. By systematically capturing key components and their interrelationships, the ICAMO model provides a structured approach to analyze how leadership actions (Interventions), environmental and organizational influences (Context), participants (Actors), causal drivers (Mechanisms), and observable results (Outcomes) interact to shape leadership outcomes (Mukumbang, De Souza, & Eastwood, 2023). Interventions reflect specific leadership strategies, such as feedback sessions or team-building initiatives; Context includes organizational culture, market conditions, or team dynamics; Actors involve leaders and team members, each with unique roles and characteristics; Mechanisms capture the underlying processes triggered by interventions, like motivation or morale-boosting effects; and Outcomes represent the measurable results, such as improvements in performance or shifts in organizational culture. The ICAMO model aligns well with the quantum perspective, as it facilitates an understanding of leadership challenges as interconnected and probabilistic, where each component’s influence depends on context and interactions among all actors involved.

These integrated components of the framework as shown in **Figure 2** culminate in a robust, adaptable framework for analyzing leadership.

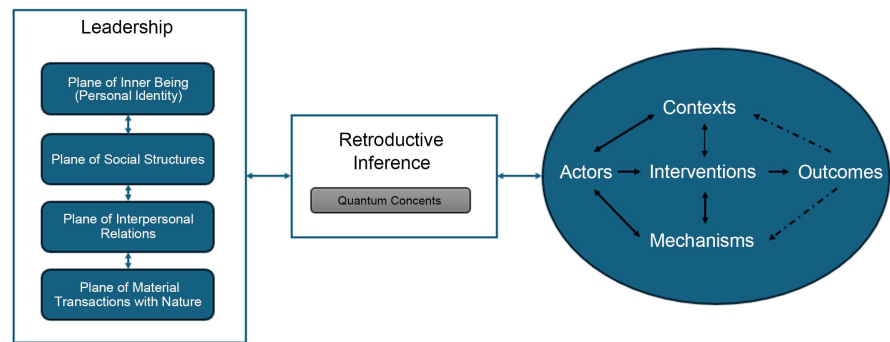


Figure 2. New framework of leadership understanding.

The framework leverages critical realism as its ontological foundation, organizes leadership within structured social planes, employs retroductive inference enhanced by quantum concepts to explore underlying mechanisms, and uses the ICAMO model to systematically analyze leadership configurations.

3.2. Practice of Understanding Leadership Phenomena

In this section, the objective is to operationalize the new framework of leadership understanding from **Figure 1** into a practical, step-by-step process, enabling leaders to apply its theoretical insights to real-world challenges. This framework integrates quantum concepts—such as superposition, entanglement, interference, and probabilistic recalibration—to bring a unique, nuanced approach to understanding and addressing leadership dynamics.

The process begins with identifying a specific leadership phenomenon, problem, or challenge. Here, the leader selects a situation that is complex, unexpected, or behaviorally rich. Using the ICAMO model, the leader maps out this situation by examining the intervention strategies, contextual factors, involved actors, underlying mechanisms, and observable outcomes. Each challenge identified is assigned a subjective probability based on its perceived relevance. These probabilities are then converted into quantum amplitudes representing a superposition of challenges. In this state, each amplitude reflects the relative influence of each challenge on the overall situation, capturing multiple influences at once.

Following this foundational analysis, the next step involves a deeper examination of the factors influencing the identified challenges, structured across the framework's four social planes: Material Transactions with Nature, Interpersonal Relations, Social Structures, and Inner Being. The quantum concept of entanglement is applied here to understand interdependencies across these planes; for instance, team dynamics (within Interpersonal Relations) may be intricately linked with organizational culture (within Social Structures), so that changes in one factor could have direct effects on the other. By systematically identifying these entangled relationships and assigning subjective probabilities to each factor, leaders gain a structured overview of the most influential elements, establishing a solid basis for further exploration.

Building on this understanding, leaders then apply counterfactual thinking to

explore hypothetical changes and understand how different elements within the system influence one another. This approach, grounded in quantum interference principles, involves developing “What If” scenarios for each ICAMO component—intervention, context, actors, mechanisms, and outcomes—allowing the leader to assess how altering each factor could impact the results. For example, they might explore whether performance improvements would still occur without structured feedback or if high team morale would persist under high stress instead of high trust. Such scenarios reveal constructive and destructive interference effects, showing how certain factors can either amplify or reduce each other’s impact. This counterfactual analysis clarifies key interdependencies, enabling leaders to isolate critical mechanisms and refine their approach to address the identified challenges more effectively.

With these insights in hand, leaders move to cross-case analysis to identify dominant mechanisms and regularities across different scenarios. This phase, which employs an iterative, abductive process, involves looking for recurring patterns and causal mechanisms across multiple cases. Using insights from counterfactual scenarios, leaders adjust configurations and update quantum amplitudes iteratively, reflecting an evolving understanding of each challenge’s impact. This recalibration mirrors probabilistic adjustment in quantum systems, where each update refines the representation of influential factors, ultimately revealing which elements consistently exert the greatest influence across different contexts.

The process culminates in synthesizing the findings into practical, actionable strategies. By recalculating quantum amplitudes, leaders can prioritize challenges based on their relative significance, with the highest amplitudes pointing to the areas that demand immediate attention. The iterative refinement of these quantum states, represented in the new quantum state allows leaders to continually adjust their focus as new information and challenges arise. This dynamic quantum state reflects an updated understanding of leadership priorities, providing a robust, context-sensitive foundation for informed decision-making. Through the integration of quantum concepts—superposition, entanglement, interference, and probabilistic recalibration—this framework equips leaders with a multidimensional perspective that accommodates complexity and adaptability. Leaders can thus make more nuanced, interdependence-aware decisions, navigating challenges with a quantum-inspired understanding of leadership dynamics.

3.3. Process of Retroductive Inference of Real-World Leadership Challenges

In this section, we explore a systematic approach to understanding and addressing complex leadership challenges using retroductive inference. The process is designed to integrate theoretical models with real-world scenarios, providing a structured framework to identify, analyze, and refine leadership strategies. Through eight progressive steps, this approach combines the ICAMO model, counterfactual thinking, quantum-inspired calculations, and abductive reasoning to uncover the un-

derlying dynamics of leadership situations.

The journey begins in Step 1, where a leadership phenomenon or challenge is identified and mapped using the ICAMO framework, considering interventions, context, actors, mechanisms, and outcomes. This forms the basis for framing the leadership issue. Step 2 deepens this analysis by categorizing the influencing factors across four planes: material transactions, interpersonal relations, social structures, and personal identity. This categorization highlights the multidimensional nature of leadership dynamics.

In Step 3, counterfactual thinking is employed to explore hypothetical variations in influencing factors, such as “What if structured feedback was removed from the team dynamic?” This approach identifies interdependencies like how feedback influences trust and morale, helping leaders refine strategies to strengthen team relationships and refining the understanding of causal mechanisms. Tables and iterative questioning methods provide a clear structure to this exploratory phase. The analysis transitions to Steps 4 through 6, where cross-case analysis is conducted to identify dominant patterns and mechanisms. For instance, analyzing two teams with different leadership styles might reveal recurring patterns in how open communication impacts team performance across contexts, offering insights into recurring causal relationships and systemic dynamics.

Next, the findings are quantitatively analyzed through quantum-inspired methodologies. Assigning probabilities and amplitudes to identified issues highlights the interplay of positive and negative influences. For example, using quantum-inspired calculations, a leader can evaluate whether prioritizing team cohesion (positive influence) outweighs challenges like role overload (negative influence) to determine the most impactful focus area. Finally, in Steps 7 and 8, the focus shifts to synthesizing these insights into actionable strategies. The process culminates in the development of robust, adaptable explanations that guide leaders in addressing challenges effectively, ensuring the solutions are both evidence-based and applicable across varied contexts. This comprehensive approach empowers leaders to navigate complexities with precision and adaptability.

3.3.1. Step 1: Identify a Leadership Phenomenon, Problem, or Challenge

Start by selecting a leadership situation with various leadership challenges that warrant in-depth analysis, particularly one involving unexpected, complex, or noteworthy behaviors. Use the ICAMO model to map out the initial components of the situation and challenges:

- **Intervention:** Describe the leadership actions or strategies used, such as feedback sessions or team-building efforts.
- **Context:** Identify environmental factors influencing the leadership challenge, including organizational culture, market conditions, or team dynamics.
- **Actors:** Define the key individuals involved, such as leaders and team members, noting any relevant characteristics or roles.
- **Mechanisms:** Explore the processes activated by the intervention, like motivation, morale, or conflict resolution mechanisms.

- **Outcome:** Observe the measurable results or effects, such as performance improvements or shifts in morale.

Initial Beliefs and Probability Calculation (Superposition)

Challenges such as balancing innovation with operational efficiency can be viewed as existing in a ‘superposition state,’ where each is prioritized based on its contextual relevance. For example, a leader may toggle between long-term planning and immediate problem-solving based on team needs.

Each identified case is assigned a subjective probability based on its perceived significance, representing the likelihood that each challenge impacts the leadership dynamic.

To express these probabilities in a quantum context, they are converted into quantum amplitudes. Each amplitude is calculated by taking the square root of the respective probability, as shown below:

$$\begin{aligned} a &= \sqrt{P(\text{Challenge 1})} \\ b &= \sqrt{P(\text{Challenge 2})} \\ c &= \sqrt{P(\text{Challenge 3})} \\ d &= \dots \end{aligned}$$

These amplitudes create an initial quantum state $|\psi_0\rangle = a|F\rangle + b|T\rangle + c|R\rangle$ for the leader’s situation, representing the combined influence of each identified challenge.

This composite state provides a probabilistic representation of the leadership situation, with each amplitude indicating the relative weight or influence of each challenge.

3.3.2. Step 2: Assessing Influencing Factors

Identifying the Leadership-factors influencing each of the various challenges. This structured analysis helps clarify which challenge has the greatest impact by judging the personal belief with a subjective probability.

Structured breakdown of **leadership influencing factors** (see **Table 5**) categorized across four distinct planar.

Table 5. Leadership influencing factors categorized across the four planes.

Planes	Influencing Factors
Plane of Material Transactions with Nature	VUCA environments, multi-crisis contexts, organizational change, workplace conditions, and contextual conditions.
Plane of Interpersonal Relations	Social interaction, roles, collaboration, power dynamics, conflict management, motivation, shared goals, trust, and sensemaking.
Plane of Social Structures	Institutional structures, coercive power, cultural norms, role ambiguity, workplace structures, and psychological needs (autonomy and competence).
Plane of Inner Being (Personal Identity)	Self-efficacy, psychological capital, personal power, emotional regulation, autonomy, adaptive performance, reflection, and motivation.

3.3.3. Step 3: Counterfactual Thinking to Understand Mechanism Interdependencies

Counterfactual thinking is a process that involves exploring hypothetical changes to the influencing factors identified in step 2. By envisioning alternate scenarios, we can examine how different components and their interdependencies might affect outcomes. This approach helps isolate which elements are critical and understand how they interact within the system.

Develop “What If” Variations for Each Component

In exploring the effectiveness of leadership interventions, systematically generating and analyzing “What If” variations offer valuable insights. By altering individual components—such as interventions, contexts, actor traits, mechanisms, or outcomes—leaders can better understand the dependencies and interactions that drive success. This structured approach helps pinpoint critical factors, test assumptions, and refine strategies for real-world application.

Table 6 outlines the different types of “What If” variations, offering examples to illustrate how each can be applied. These variations form the basis for systematically evaluating the importance and interplay of various components within a leadership framework.

Table 6. “What If” variations for each ICAMO-component.

Component Type	Description	Example Question
Intervention Variations	Evaluate the significance of a specific intervention by altering or removing it.	“What if structured feedback was removed? Would performance still improve?”
Context Variations	Assess how changes in context affect the impact of the intervention.	“What if the team operated under high stress instead of high trust? Would structured feedback have the same effect?”
Actor-Related Variations	Explore how individual attributes influence the outcome.	“What if the leader lacked experience in giving feedback? Would structured feedback yield positive results?”
Mechanism-Related Variations	Test if the mechanism behind the intervention is necessary for success.	“What if feedback failed to increase motivation? Would team performance still improve?”
Outcome-Specific Variations	Investigate if outcomes depend on the intervention or other factors.	“What if team performance didn’t improve despite structured feedback?”

While **Table 6** focuses on generating “What If” scenarios to explore potential variations in interventions and their contexts, **Table 7** delves deeper into counterfactual tests. These tests assess causality and interaction, distinguishing between necessary and sufficient conditions to identify the essential components driving desired outcomes.

This progression from exploring variations to testing causality enables a comprehensive understanding of the dynamics at play, empowering leaders to design strategies rooted in evidence and adaptability.

Table 7. Counterfactual tests for causality and mechanism interaction.

Test Type	Purpose	Example Question
Necessary Conditions	Determine if a specific intervention/component is essential for the outcome.	“Is structured feedback necessary to improve motivation, or could a different intervention trigger motivation?”
Sufficient Conditions	Check if a condition alone can produce the outcome.	“Would performance improve simply with high motivation, without feedback?”

Iteratively Refine Questions for Depth

An iterative approach to refining questions enables a progressive deepening of analysis. Starting with broad, open-ended “What If” questions help uncover initial insights, while subsequent narrowing down to more specific scenarios allows for a clearer understanding of the interplay between components, mechanisms, and context. This method ensures that each question builds on the knowledge gained, fostering a comprehensive exploration of dependencies and dynamics.

Table 8 outlines the stages of iterative question refinement, with examples illustrating how the process evolves.

Table 8. Stages of iterative question refinement, with examples illustrating how the process evolves.

Stage	Purpose	Example Question
Begin Broad	Explore general changes to identify initial insights.	“What if feedback was less structured?”
Narrow Down	Focus on detailed, specific scenarios as understanding deepens.	“What if only high performers received structured feedback?”

This iterative questioning approach helps clarify each component’s role, the impact of variations, and the interplay among mechanisms, actors, and context. **Table 9** shows examples of the results of counterfactual thinking.

Table 9. Results of counterfactual thinking (example).

Planar	Factors	Findings
Plane of Interpersonal Relations	Team dynamics, conflict management, collaboration	Unresolved team conflicts are preventing Markus from maintaining cohesion and leadership clarity.
Plane of Interpersonal Relations	Shared decision making, power dynamics, trust	Mixed feedback from the team creates a misalignment, amplifying leadership challenges and fostering uncertainty.
Plane of Social Structures	Institutional structures, role ambiguity	Ambiguity in Markus’s leadership role, alongside conflicting expectations, adds to the confusion and role overload.
...

Table 9 illustrates the outcomes of counterfactual thinking, offering a structured lens to explore how changes in specific factors can influence the dynamics within interpersonal relations, social structures, and beyond. These findings provide a foundation for deeper analysis by categorizing interdependencies among the identified factors.

Categorization of Interdependencies

Building on the insights from **Table 9**, the next step involves systematically categorizing the interdependencies between influencing factors. By employing quantum-inspired concepts such as entanglement, superposition, and interference, this approach identifies nuanced interrelations that contribute to overarching challenges. Each issue is evaluated for its subjective probability, reflecting its relative impact and likelihood.

These probabilities are normalized to ensure the total probability sums to 1, allowing for a coherent understanding of the system’s behavior. This process bridges the insights from counterfactual analysis into actionable categorizations, as detailed in **Table 10**.

Table 10. Issues with descriptions and probabilities (examples).

Issue	Description	Subjective Normalized Probability
Issue 1: Entanglement Between Personal and Professional Life	Markus’s personal stress (possibly family or health concerns) entangles with his professional challenges. This entanglement is reducing his focus and emotional energy at work.	0.1428
Issue 2: Entanglement Between Team Dynamics and Organizational Culture	Markus’s team is directly influenced by the larger organizational culture. Lack of support from upper management or weak cultural norms around conflict resolution worsens the internal team conflicts. This entanglement reduces Markus’s ability to resolve team dynamics effectively and contributes to his sense of Role Overload.	0.1667
...		

Having categorized the interdependencies and assigned normalized probabilities to each issue in **Table 9**, the next step involves translating these probabilities into quantum amplitudes. This calculation provides a foundation for analyzing the system’s complexity using quantum-inspired methods. By applying the general formula $a_i = \sqrt{P_i}$, we extract the quantum amplitudes that reflect the influence and interplay of each factor. These amplitudes form the basis for further modeling and interpretation, enabling a deeper understanding of how individual issues collectively shape the system’s behavior.

Calculation of Quantum Amplitudes

Calculating quantum amplitudes with the general formula:

$$a_i = \sqrt{P_i}$$

For each issue, the amplitudes will be calculated:

$$a_1 = \sqrt{0.1428} \approx 0.3770$$

$$a_2 = \sqrt{0.1667} \approx 0.4082$$

$$a_n = \dots$$

Having derived the quantum amplitudes for each issue, as illustrated in the preceding calculations, the analysis now transitions from individual probabilities and amplitudes to a broader, systemic exploration. Steps 4 to 6 focuses on integrating these results into a cross-case analysis aimed at uncovering dominant mechanisms and patterns. By synthesizing insights from quantum-inspired calculations and abductive reasoning, this phase deepens our understanding of the underlying dynamics, ensuring that the interplay of factors is systematically evaluated across different contexts. This holistic approach lays the groundwork for identifying robust causal relationships and refining intervention strategies in subsequent steps.

3.3.4. Step 4 to Step 6: Conduct Cross-Case Analysis to Find Dominant Mechanisms and Regularities

The iterative process involves three core actions. First, generate and test propositions by applying abductive reasoning and insights from counterfactual scenarios (Step 3) to understand why certain interventions work. Next, adjust configurations iteratively, modifying the model as new insights emerge from each challenge. Finally, identify and validate dominant patterns through cross-challenge analysis, looking for recurring mechanisms and contextual elements that suggest robust causal relationships.

Mapping Each of the Issues to the Leadership Challenges They Affect (Examples):

Issue 1: Entanglement Between Personal and Professional Life

- Challenge Affected: Impostor Syndrome ($|I\rangle$).
- Impact: Exacerbates Impostor Syndrome by reducing focus and emotional energy.

Issue 2: Entanglement Between Team Dynamics and Organizational Culture

- Challenges Affected: Team Dynamics ($|T\rangle$) and Role Overload ($|R\rangle$).
- Impact: Worsens team dynamics and contributes to Role Overload.

Issue n: ...

To better understand the interplay between specific issues and the leadership challenges they impact, we have mapped these relationships in the following **Table 11**. This table provides a structured overview of how various issues contribute—positively or negatively—to different leadership challenges, highlighting key areas where focus and intervention might be necessary.

The mapping clearly illustrates the varying degrees and directions of influence that each issue exerts on leadership challenges. By identifying these contributions, leaders can prioritize strategies to mitigate negative effects and harness positive influences, ultimately fostering more effective leadership and team dynamics.

Building on the insights from **Table 10**, we assign quantum amplitudes to each

issue to quantify their respective influences on leadership challenges. This quantum-based representation integrates both positive contributions (entanglement) and negative contributions (interference) to derive a holistic understanding of each challenge. The computations in **Table 12** highlight the interplay of these contributions, providing a quantitative framework for analyzing the complexities of leadership dynamics.

Table 11. Mapping of the issues to challenges and its contribution (examples).

Challenge	Issues 1	2	3	4	5	6	...
a	+				-	-	
b		+	+	+		-	
c		+			-		
...							

Legend: “+” = positive contribution, “-” = negative contribution.

Assigning Quantum Amplitudes to Issues

In **Table 12**, the total amplitude for each challenge is calculated by summing the positive and negative contributions from the identified issues. These total amplitudes are then squared to yield the probabilities of each challenge’s occurrence, emphasizing their respective significance. For instance, the challenge of “Impostor Syndrome” is influenced by Issue 1 (positive contribution) and Issues 5 and 6 (negative contributions). The total amplitude and resulting probability reflect the net impact of these issues on the challenge.

Table 12. Computing total amplitudes for each challenge (examples).

Challenge	Computation
Impostor Syndrome	Positive Contribution (Entanglement): a_1 (Issue 1): +0.3770 Negative Contribution (Interference): a_5 (Issue 5): -0.3935, a_6 (Issue 6): -0.4082 Total amplitude for $ I\rangle$: $A_I = +a_1 - a_5 - a_6 = +0.3770 - 0.3935 - 0.4082 = -0.4247$ Probability for $ I\rangle$: $P_I = A_I ^2 = (-0.4247)^2 = 0.1804$
...	

Updated Beliefs and Probability Recalculation

Following the insights, the subjective probabilities for each identified challenge are recalibrated, reflecting a revised understanding of their relative importance. These updated probabilities signify the recalculated weight of each challenge within the leader’s experience.

The recalculated probabilities are converted into new quantum amplitudes:

$$a' = \sqrt{P'(\text{Challenge } 1)}$$

$$b' = \sqrt{P'(\text{Challenge 2})}$$

$$c' = \sqrt{P'(\text{Challenge 3})}$$

The updated quantum state ψ_1 represents the leader's revised perspective.

$$\psi_1 = a'|I\rangle + b'|T\rangle + c'|R\rangle$$

This state captures the adjusted significance of each challenge, with the highest amplitude indicating the area that requires primary focus.

At this juncture, the recalibrated quantum state ψ_1 serves as the foundation for deeper analysis. By identifying the challenge with the highest amplitude, leaders gain clarity on their primary focus, enabling them to direct their attention and resources effectively. The transition from theoretical recalculations to actionable strategies marks a pivotal shift, emphasizing the application of insights in real-world scenarios.

3.3.5. Steps 7 and 8: Develop the Best Explanation

Synthesize findings grounded in counterfactual-tested insights and actionable strategies. Create guidance on leadership strategies adaptable to real-world contexts. Regularly test across new contexts, ensuring its robustness and applicability in diverse leadership scenarios.

3.4. Retroductive Inference for Real-World Leadership Challenges

Illustrating the practical implications of retroductive inference in addressing real-world leadership challenges highlights its relevance in guiding actionable strategies for leaders, shaping informed expectations, and supporting sound decision-making (Lemon & Verhoef, 2016). To demonstrate this process in a real-world scenario, the following use case of Markus Berger will be examined.

3.4.1. The Use Case Situation

Markus Berger, newly promoted to team leader, faces a set of interrelated challenges that undermine his confidence and effectiveness. Plagued by impostor syndrome, he doubts his qualifications, leading him to second-guess his decisions and interpret feedback as criticism, which fuels his fear of failure. This self-doubt drains his mental energy, creating a cycle of insecurity.

Inherited team tensions add to his struggle, as unresolved conflicts and alliances hinder his attempts to build cohesion and assert authority. Markus's lack of experience in conflict management intensifies his hesitation to intervene, reinforcing his feelings of inadequacy. Additionally, a significant increase in workload leaves him overwhelmed, as he juggles team management and project duties, amplifying stress and eroding his focus and job satisfaction.

These issues collectively impair his decision-making, as fear of revealing inadequacies causes him to overthink and delay choices, frustrating both himself and his team. This hesitation undermines his authority and perpetuates a feedback loop of self-doubt and avoidance. Markus feels trapped in a cycle of stress, insecurity, and exhaustion, motivating his search for strategies to build confidence and navigate his role more effectively.

3.4.2. Step 1: Identify a Leadership Phenomenon, Problem, or Challenge

Usage of the ICAMO model to map out the initial components of the use case and challenges (see **Table 13**):

Table 13. ICAMO-model analysis of the use case.

ICAMO Component	Description
Intervention	<p>Attempted Team Building: Markus’s efforts to create collaboration failed due to insecurity and lack of conflict management skills.</p> <p>Ongoing Critical Feedback: Team feedback worsens Markus’s insecurity, creating a need for validation that exhausts him and lowers confidence.</p> <p>Decision-Making Delays: Markus’s insecurity-driven hesitation causes frustration and disrupts team dynamics, risking his authority.</p>
Context	<p>Inherited Team Dynamics: Existing team conflicts and divisions make it challenging for Markus to lead effectively.</p> <p>Increased Workload: New responsibilities and ongoing conflicts increase stress, affecting health and productivity.</p> <p>Organizational Pressure for Performance: High expectations add to Markus’s stress and the pressure to succeed.</p>
Actors	<p>Markus: New team leader struggling with impostor syndrome, which weakens confidence and decision-making.</p> <p>Team Members: Unresolved team conflicts and alliances create additional leadership challenges for Markus.</p> <p>Previous Leader: The former leader left unresolved conflicts, making Markus’s leadership transition difficult.</p>
Mechanisms	<p>Impostor Syndrome: Markus’s self-doubt fuels fear of failure and hinders decision-making, lowering confidence and responsiveness.</p> <p>Conflict Avoidance: Markus avoids conflicts to prevent escalation, which maintains unresolved team issues and dysfunction.</p> <p>Role Overload: Increased workload and limited management experience leave Markus feeling stretched and fatigued.</p> <p>Feedback Sensitivity: Markus’s insecurity makes him highly sensitive to feedback, intensifying self-doubt and impeding learning.</p>
Outcomes	<p>Erosion of Decision-Making: Self-doubt causes Markus to delay decisions, reducing team productivity and authority.</p> <p>Low Confidence & Lack of Assertiveness: Markus’s hesitance to assert himself undermines confidence and reinforces insecurity.</p> <p>Increased Stress & Lower Job Satisfaction: Cumulative stress from conflicts and self-doubt affect Markus’s well-being.</p> <p>Negative Feedback Loop: Ongoing self-doubt and avoidance create a cycle of challenges in team dynamics and personal exhaustion.</p>

After analyzing the use case using the ICAMO model, the next step involves determining the subjective probabilities for the three most critical challenges.

Initial Beliefs and Probability Calculation (Superposition)

For reasons of simplification, the 3 most relevant challenges were selected and the probabilities were chosen.

Based on the ICAMO-descriptions, the following three challenges appear to be the most critical:

1) Ongoing Critical Feedback from Team (Feedback Sensitivity): This feedback exacerbates Markus's insecurities and intensifies his impostor syndrome, creating a negative feedback loop that impacts his confidence, decision-making, and overall mental state.

2) Decision-Making Delays and Team Frustration: Markus's hesitancy and delayed decision-making, driven by fear of failure, directly impacts the team's morale and efficiency, and undermines his authority.

3) Impostor Syndrome: This underlying insecurity feeds his avoidance behaviors, decision-making difficulties, and susceptibility to stress, creating a core psychological barrier that affects his entire leadership approach.

Assign Probabilities to Each Challenge

Assign subjective probabilities based on the relative impact of each of these challenges on Markus's leadership dynamic:

- Ongoing Critical Feedback from Team (Feedback Sensitivity): $P = 0.4$
- Decision-Making Delays and Team Frustration: $P = 0.35$
- Impostor Syndrome: $P = 0.25$

Convert to Quantum Amplitudes and Normalize

Take the square root of each probability to express these as quantum amplitudes.

1) Amplitude for Feedback Sensitivity: $a = \sqrt{0.4} \approx 0.632$

2) Amplitude for Decision-Making Delays: $b = \sqrt{0.35} \approx 0.592$

3) Amplitude for Impostor Syndrome: $c = \sqrt{0.25} = 0.5$

Now, to ensure the sum of the squared amplitudes equals 1 (normalization):

$$a^2 + b^2 + c^2 = 0.632^2 + 0.592^2 + 0.5^2 = 1$$

Construct the Initial Quantum State $|\psi_0\rangle$

The initial quantum state $|\psi_0\rangle$ for Markus's situation, representing the superposition of challenges impacting his leadership, is given by:

$$|\psi_0\rangle = 0.632|F\rangle + 0.592|D\rangle + 0.5|I\rangle$$

where:

- $|F\rangle$: State representing the influence of Feedback Sensitivity.
- $|D\rangle$: State representing Decision-Making Delays.
- $|I\rangle$: State representing Impostor Syndrome.

3.4.3. Step 2: Assessing Influencing Factors

Based on ICAMO-model analysis (Table 13) this step assesses further influencing

factors across the four planes (see **Table 14**), as described in the use case, to identify how each influencing factor impacts the three selected challenges: **Ongoing Critical Feedback from Team (Feedback Sensitivity)**, **Decision-Making Delays and Team Frustration**, and **Impostor Syndrome**. These factors will help clarify which challenge has the greatest impact on Markus’s leadership and confidence.

The extended insights from analysis of the four planes reveal that Markus’s challenges stem not only from his insecurity but also from structural, cultural, and psychological factors. The VUCA environment, critical team culture, and unclear role structures place additional pressure on him. This layered analysis highlights that Markus’s difficulties are best understood as an interplay of internal and external factors, each influencing his leadership effectiveness.

Table 14. Advanced ICAMO-model analysis of the use case.

ICAMO Component	Description
Intervention	<ul style="list-style-type: none"> • Attempted Team Building: Markus’s efforts to foster team collaboration fail due to insecurity and lack of conflict management skills. Additionally, team dynamics marked by power struggles pose further challenges for Markus. • Critical Feedback and Contextual Shifts: The VUCA (Volatile, Uncertain, Complex, Ambiguous) work environment and critical feedback intensify Markus’s insecurity. His need for validation leads to exhaustion and further lowers his self-confidence. • Decision-Making Delays due to Role Ambiguity: Unclear role expectations cause frustration within the team and impair Markus’s ability to make and enforce decisions.
Context	<ul style="list-style-type: none"> • Inherited Team Dynamics: Existing conflicts and alliances within the team make it challenging for Markus to lead effectively. He is torn between asserting authority and fearing he may appear too forceful. • VUCA Environment and Workplace Conditions: The complex, uncertain work environment places significant demands on Markus, exacerbating his insecurity and stress, as he must quickly adapt in an unstable setting. • Organizational Pressure and Cultural Norms: High organizational expectations and a culture of frequent feedback may indicate limited support for new leadership. This places additional strain on Markus, contributing to heightened feelings of insecurity and criticism.
Actors	<ul style="list-style-type: none"> • Markus: A new team leader grappling with impostor syndrome, which weakens his confidence and decision-making skills, especially in an environment that requires rapid adaptability. • Team Members: Unresolved team conflicts and alliances create additional leadership challenges for Markus. Power dynamics and a lack of trust make it difficult for him to establish a clear role. • Previous Leader and Cultural Expectations: The former leader left unresolved conflicts, complicating Markus’s transition. Additionally, the team culture offers Markus limited support, intensifying his feelings of insecurity.

Continued

- | | |
|-------------------|--|
| Mechanisms | <ul style="list-style-type: none"> • Impostor Syndrome and Self-Efficacy: Markus's self-doubt undermines his ability to lead, and his insecurity is amplified by team feedback, which further diminishes his sense of self-efficacy. These doubts hinder his capacity to use feedback constructively and make confident decisions. • Conflict Avoidance and Emotional Regulation Challenges: Markus avoids conflicts to prevent escalation, which maintains unresolved team tensions and affects his emotional stability. He struggles with emotional regulation, leading to overthinking and avoidance behavior. • Role Overload and Adaptive Performance: The increasing demands of his role and lack of management experience leave Markus feeling fatigued and unprepared for the need to adapt quickly. His adaptive performance is limited due to these pressures and lack of support. |
| Outcomes | <ul style="list-style-type: none"> • Erosion of Decision-Making Ability: Self-doubt leads to decision-making delays, weakening team productivity and Markus's authority. • Low Confidence and Lack of Assertiveness: Markus's hesitation to assert himself undermines his confidence and reinforces insecurity, further intensified by organizational cultural norms and expectations. • Increased Stress and Lower Job Satisfaction: Cumulative stress from conflicts and self-doubt affects Markus's well-being and job satisfaction. The VUCA environment and critical team culture lead to feelings of overwhelm and decrease job enjoyment. • Negative Feedback Loop and Limited Emotional Resilience: Ongoing self-doubt and conflict avoidance create a feedback loop where negative emotions and team dynamics lead to further exhaustion. His emotional resilience is weakened, restricting his adaptability. |

Influencing Factors for Each Challenge

Below, the influencing factors most relevant to each challenge are categorized based on subjective impact, guiding the assignment of probabilities:

Challenge 1: Ongoing Critical Feedback from Team (Feedback Sensitivity)

The critical feedback Markus receives, especially in the VUCA (Volatile, Uncertain, Complex, Ambiguous) environment, significantly exacerbates his insecurity. His need for validation grows, leading to exhaustion and a further decline in self-confidence. The organization's high expectations and feedback-heavy culture appear unsupportive of new leaders, intensifying Markus's sensitivity to criticism and his feelings of inadequacy. Markus, as a new leader with impostor syndrome, already struggles with confidence, and the unresolved conflicts and alliances within the team further complicate his ability to interpret feedback constructively. Mechanisms such as his impostor syndrome and low self-efficacy make him particularly sensitive to feedback, which reinforces his self-doubt and weakens his leadership abilities. This feedback cycle also affects his confidence and assertiveness, leaving him hesitant in his role. Ultimately, these dynamics create a negative feedback loop that drains Markus's emotional resilience, limiting his adaptability in a challenging team environment.

Challenge 2: Decision-Making Delays and Team Frustration

Markus faces significant challenges in making timely decisions, partly due to un-

clear role expectations. The ambiguity around his responsibilities leads to hesitation, causing frustration among team members and undermining his credibility as a leader. The existing conflicts within the team further delay his decisions, as he struggles to navigate the complex team dynamics while establishing his authority. Additionally, the demands of the VUCA environment, which require quick adaptability, exacerbate his hesitation and stress. The unresolved conflicts left by the previous leader also contribute to Markus's decision-making delays, as he finds it difficult to assert authority in a role that lacks clear structure. Markus's tendency to avoid conflicts only worsens the delays, as unresolved issues persist within the team. This avoidance behavior stems from emotional regulation challenges, as he attempts to sidestep situations that may lead to confrontation. Furthermore, Markus's role overload and limited management experience leave him feeling stretched thin, reducing his capacity to make decisions effectively and in a timely manner. Consequently, his self-doubt and avoidance impair his decision-making ability, weakening team productivity and his authority. The cumulative stress from delayed decisions and growing team frustration also affects his well-being and job satisfaction.

Challenge 3: Impostor Syndrome

Markus's impostor syndrome is a fundamental challenge that impacts multiple aspects of his leadership. His insecurity and lack of conflict management skills hinder his attempts to foster team collaboration. The complex and demanding VUCA environment only amplifies his impostor syndrome, as he feels increasingly overwhelmed and doubts his capacity to lead. As a new team leader grappling with impostor syndrome, Markus struggles with insecurity, which erodes his confidence in his role. His self-doubt weakens his sense of self-efficacy, making him particularly sensitive to criticism and hesitant to assert his authority. This lack of assertiveness, fueled by impostor syndrome, undermines his confidence and reinforces his insecurities. The ongoing cycle of self-doubt and avoidance creates a feedback loop that drains his emotional resilience, hindering his ability to adapt and grow within his leadership role.

3.4.4. Step 3: Counterfactual Thinking to Understand Mechanism Interdependencies

Using counterfactual thinking, we explore hypothetical "What If" scenarios to understand the interdependencies among the influencing factors identified in Step 2. This will help clarify which components are critical and how they interact, ultimately allowing us to identify the main causes and quantify their relative impact through normalized probabilities.

"What If" Variations for Each Component

The following **Table 15** explores hypothetical "What If" scenarios for each ICAMO-model component affecting Markus's leadership.

Each variation considers how adjustments to the context, interventions, actor characteristics, mechanisms, and outcomes might influence his leadership effectiveness. The next step shows how the interdependencies between the aspects of the what-if analysis looks like.

Table 15. “What If” variations for each ICAMO-component.

ICAMO-Component	Hypothetical Variation	Potential Impact on Markus
Intervention Variations	What if feedback from the team was supportive instead of critical?	Supportive feedback might reduce impostor syndrome and decision-making delays by boosting confidence and acceptance. Critical feedback appears to be a key factor in his self-doubt.
	What if Markus was provided structured mentorship in team conflict management?	Structured mentorship could decrease uncertainty, offering strategies to manage team dynamics effectively, reducing decision-making delays and easing role overload.
Context Variations	What if the team operated in a high-support environment instead of unresolved tensions?	A supportive, high-trust environment might make Markus feel more secure in his role, potentially reducing impostor syndrome and easing decision-making.
	What if Markus’s workload was manageable rather than overwhelming?	A manageable workload could reduce role overload, allowing time for reflection and proactive leadership, and decreasing insecurities linked to feeling perpetually behind.
Actor-Related Variations	What if Markus had previous experience in conflict management?	Previous experience would likely boost Markus’s confidence in interventions, reducing hesitation and improving decision-making, highlighting experience as a major contributor to confidence.
	What if Markus’s team members were accustomed to collaborative conflict resolution?	If the team had collaborative conflict norms, Markus might face fewer challenges in establishing authority, indicating the role of team norms in leadership effectiveness.
Mechanism-Related Variations	What if critical feedback did not diminish Markus’s confidence?	Resilience to feedback could allow Markus to leverage criticism constructively, reducing self-doubt and decision delays, emphasizing emotional regulation as a crucial skill.
	What if decision-making hesitation did not lead to team frustration?	If hesitation did not impact team morale, delays might have less effect on leadership authority, though team morale appears crucial in influencing Markus’s insecurities.
Outcome-Specific Variations	What if decision-making improved without changes to impostor syndrome?	This tests if decision-making can improve independently of self-doubt, although insecurity likely remains a significant underlying factor of hesitation.
	What if team dynamics improved despite Markus’s role overload?	Improved team cohesion could reduce Markus’s stress, suggesting that addressing team dynamics is crucial in mitigating leadership challenges associated with overload.

Categorization of Interdependencies

The results of the what-if analysis (see **Table 15**) can be categorized as issues (see **Table 16**) by applying quantum concepts such as entanglement, superposition, and interference with subjective probabilities based on their expected impact:

Table 16. Categorizing interdependencies as issues.

Issue	Description	Subjective Normalized Probability
Issue 1: Entanglement Between Feedback Sensitivity and Self-Doubt	Critical feedback amplifies Markus’s self-doubt and impacts his ability to handle criticism, which exacerbates his decision-making delays.	0.35
Issue 2: Entanglement Between Team Dynamics and Leadership Authority	Team conflicts and lack of cohesion diminish Markus’s perceived authority, fueling his hesitation and reinforcing feelings of inadequacy.	0.25
Issue 3: Interference of Role Overload with Emotional Resilience	Markus’s overwhelming workload reduces his emotional resilience and energy, contributing to his burnout and intensifying stress in handling team conflicts.	0.20
Issue 4: Superposition of Role Ambiguity and Psychological Needs	Unclear role expectations and unmet psychological needs (competence, validation) reinforce Markus’s impostor syndrome and undermine his ability to lead effectively.	0.15
Issue 5: Interference Between Low Self-Efficacy and Decision-Making	Markus’s low self-efficacy limits his confidence in decision-making, creating a feedback loop that intensifies his hesitation and undermines his leadership presence.	0.05

After determining the relationships and their subjective probabilities, the quantum amplitudes for the issues are calculated.

Calculation of Quantum Amplitudes

The following **Table 17** provides the calculation of quantum amplitudes for each issue Markus faces, representing them in the initial quantum state $|\psi_0\rangle$. Each issue is represented by a specific amplitude, derived from the square root of its assigned probability, and mapped to a corresponding component of his leadership challenges.

The initial quantum state $|\psi_0\rangle$ representing Markus’s issues is given by:

$$|\psi_0\rangle = 0.592 |F\rangle + 0.5 |T\rangle + 0.447 |R\rangle + 0.387 |A\rangle + 0.224 |S\rangle.$$

This quantum representation shows the entangled nature of Markus’s challenges, highlighting how his sensitivity to feedback and unresolved team dynamics most significantly affect his leadership confidence and decision-making ability.

3.4.5. Steps 4 to 6: Conduct Cross-Case Analysis and Recalibration

This section outlines Steps 4 through 6, applying cross-case analysis to identify

dominant mechanisms and recalibrating quantum amplitudes for each leadership challenge Markus faces. The iterative process identifies which issues significantly impact each challenge by using counterfactual insights from Step 3.

Table 17. Calculation of quantum amplitudes.

Issue	Amplitude Calculation	Amplitude Value
Issue 1: Feedback Sensitivity and Self-Doubt ($ F\rangle$)	$a_1 = \sqrt{0.35}$	$a_1 \approx 0.592$
Issue 2: Team Dynamics and Leadership Authority ($ T\rangle$)	$a_2 = \sqrt{0.25}$	$a_2 = 0.5$
Issue 3: Role Overload and Emotional Resilience ($ R\rangle$)	$a_3 = \sqrt{0.20}$	$a_3 \approx 0.447$
Issue 4: Role Ambiguity and Psychological Needs ($ A\rangle$)	$a_4 = \sqrt{0.15}$	$a_4 \approx 0.387$
Issue 5: Self-Efficacy and Decision-Making ($ S\rangle$)	$a_5 = \sqrt{0.05}$	$a_5 \approx 0.224$

Conduct Cross-Case Analysis to Find Dominant Mechanisms and Regularities

To find dominant patterns, each identified issue is mapped to the leadership challenges it impacts (see **Table 18**). This process clarifies the contribution of each issue to the challenges of Impostor Syndrome, Team Dynamics, and Role Overload, highlighting entanglements or interference.

Table 18. Mapping issues to leadership challenges and contributions.

Challenge	Issue 1 (Feedback Sensitivity)	Issue 2 (Team Dynamics)	Issue 3 (Role Overload)	Issue 4 (Role Ambiguity)	Issue 5 (Self-Efficacy)
Impostor Syndrome ($ I\rangle$)	+		-		-
Team Dynamics ($ T\rangle$)	-	+		+	
Role Overload ($ R\rangle$)		-	+	-	

Legend: “+” = positive contribution, “-” = negative contribution.

The next step is to calculate the influence of the mapped issues regarding the challenges.

Assigning Quantum Amplitudes to Issues

Table 19 represents the calculation of total amplitudes for each leadership challenge by combining positive and negative contributions from each identified issue in the analysis. Based on the calculated amplitudes and probabilities, the probabilities for each challenge are recalibrated to reflect the adjusted significance of each issue.

This recalibration allows us to update the quantum state, resulting in a normalized representation of each challenge’s impact on Markus’s leadership role.

Table 19. Calculation of quantum amplitudes to issues.

Challenge	Positive Contribution (Entanglement)	Negative Contribution (Interference)	Total Amplitude & Probability	Normalized Probability & Amplitude	Converted Quantum Amplitude
Impostor Syndrome ($ I\rangle$)	$+a_1$ (Issue 1): +0.592	$-a_5$ (Issue 5): -0.224, $-a_3$ (Issue 3): -0.447	$A_I = +0.592 - 0.224 - 0.447 = -0.079$ $P_I = (-0.079)^2 \approx 0.0062$	Normalized Probability: 0.0062 Amplitude $P(I\rangle)$: 0.0216	a' for $ I\rangle$: $\sqrt{0.0216} \approx 0.147$
Team Dynamics ($ T\rangle$)	$+a_2$ (Issue 2): +0.5, $+a_4$ (Issue 4): +0.387	$-a_1$ (Issue 1): -0.592	$A_T = +0.5 + 0.387 - 0.592 = 0.295$ $P_T = (0.295)^2 \approx 0.087$	Normalized Probability: 0.087 Amplitude $P(T\rangle)$: 0.3033	b' for $ T\rangle$: $\sqrt{0.3033} \approx 0.55$
Role Overload ($ R\rangle$)	$+a_3$ (Issue 3): +0.447	$-a_4$ (Issue 4): -0.387, $-a_2$ (Issue 2): -0.5	$A_R = +0.447 - 0.387 - 0.5 = -0.44$ $P_R = (-0.44)^2 \approx 0.1936$	Normalized Probability: 0.1936 Amplitude $P(R\rangle)$: 0.6751	c' for $ R\rangle$: $\sqrt{0.6751} \approx 0.822$

Legend: $0.0216 + 0.3025 + 0.6751 = 0.9992 \approx 1$. This result is close enough to 1, confirming that the state is effectively normalized.

Revised Quantum State (ψ_1)

The revised quantum state representing the recalibrated significance of each leadership challenge is:

$$|\psi_1\rangle = 0.14|I\rangle + 0.55|T\rangle + 0.822|R\rangle$$

This state highlights Role Overload ($|R\rangle$) as the dominant challenge, followed by Team Dynamics ($|T\rangle$). Impostor Syndrome ($|I\rangle$), while still relevant, shows a smaller impact relative to the other challenges.

3.4.6. Steps 7 to 8: Develop the Best Explanation

The analysis reveals that Markus’s primary leadership challenges stem from role overload, team dynamics, and impostor syndrome. His new responsibilities have intensified his workload, increasing stress and diminishing his resilience. Additionally, unresolved team conflicts and critical feedback amplify his self-doubt, while an organizational culture unsupportive of new leadership further hinders his authority. Together, these elements create a feedback loop where stress and self-doubt reinforce each other, compounding his leadership struggles.

To break this cycle, Markus can employ targeted strategies to reduce role overload, improve team cohesion, and strengthen his resilience. By delegating tasks effectively, he can balance his workload, while structured team-building activities can address team dynamics and encourage constructive feedback. Developing emotional resilience through mindfulness and reflection practices, combined with guidance from a mentor, can help him gradually overcome impostor syndrome. Building a feedback-friendly environment will reduce the negative impact of criticism, allowing Markus to frame feedback as growth opportunities. These strategies, adaptable across contexts, can help Markus and other emerging leaders navigate complex leadership roles with greater confidence and efficacy.

4. Results and Discussion

4.1. Key Findings

The integration of critical realism (CR) with quantum principles offers a ground-

breaking approach to understanding leadership, rooted in the retroductive inference process of CR. Through retroduction, we identify the underlying mechanisms or conditions necessary for observed leadership phenomena to occur, going beyond mere description of surface-level behaviors. This approach enables a deeper exploration of the “why” and “how” of leadership, uncovering the causal structures that operate within complex organizational environments (Bhaskar, 1975a).

1) Uncovering Leadership Mechanisms through Retroduction and Quantum Concepts

Retroductive reasoning reveals that hidden mechanisms, such as relational dynamics and contextual factors, are central to understanding leadership, particularly in VUCA (volatile, uncertain, complex, and ambiguous) contexts. Quantum principles like entanglement and superposition help conceptualize these mechanisms by illustrating how leaders’ decisions are interconnected with broader organizational structures. **Case Study Connection:** Drawing from Markus Berger’s case study (Section 5.4), Markus’s leadership challenges—such as impostor syndrome and unresolved team dynamics—can be better understood through the lens of entanglement. For example, the conflicts between team members and Markus’s self-doubt are not isolated phenomena but are relationally intertwined. This mirrors quantum entanglement, where one component directly influences another. Retroductively, this perspective emphasizes leadership as a network of interdependent relationships, where resolving team conflicts and addressing personal insecurities are equally vital to achieving organizational cohesion (Wendt, 2014; Wu, Cormican, & Chen, 2020).

2) Retroductive Inference in Addressing Leadership Uncertainty

In uncertain environments, deterministic leadership models often fail to account for the complexity of decision-making. Retroductive reasoning, informed by Quantum Bayesianism (QBism), reframes leadership as a probabilistic process. Leaders operate by forming subjective expectations and updating these based on new information, reflecting the dynamic nature of decision-making (Fuchs, Mermin, & Schack, 2014). **Case Study Connection:** Markus’s hesitancy in decision-making, exacerbated by fear of failure, aligns with the QBism framework. By retroductively analyzing his situation, we infer that effective leadership in uncertainty requires adaptive strategies. For instance, Markus could use retroductive inference to evaluate team feedback as probabilistic data, guiding his choices while acknowledging evolving uncertainties. This highlights that leadership involves navigating multiple potential outcomes rather than adhering to fixed paths.

3) Temporal Dimensions and Retroduction in Leadership

Beckert’s (2013) concept of “fictional expectations” complements retroductive inference by showing how leaders rely on past experiences and current constraints to shape future strategies. This perspective aligns with CR’s focus on uncovering causal preconditions for effective action. **Case Study Connection:** In Markus’s case, his ability to recalibrate expectations by reflecting on past successes (such as managing smaller teams) and adapting to current pressures (e.g., organizational

deadlines) is essential. By retroductively examining his role, we see that leadership requires simultaneous engagement with past lessons, present realities, and future possibilities. For Markus, envisioning a more collaborative team dynamic while addressing immediate role ambiguity exemplifies this temporal interplay.

4.2. Theoretical Implications

Focusing on retroductive inference within critical realism (CR) strengthens the theoretical foundation of this synthesis by underscoring the importance of identifying causal mechanisms, rather than merely describing leadership traits or behaviors. Retroduction enables researchers and practitioners to infer deeper insights about the structures and powers underlying leadership, shifting the focus from observable actions to the hidden, systemic conditions that make these actions possible (Bhaskar, 1975a; Kempster & Parry, 2011). This approach aligns closely with the principles of quantum social science (QSS), as both emphasize the complexity and layered nature of reality (Wendt, 2014).

Complexity and Interconnectedness through Entanglement and Retroductive Analysis

The quantum concept of entanglement allows leadership to be viewed as a multi-layered network of interdependencies, resonating with CR's retroductive emphasis on uncovering interrelated mechanisms. CR's stratified ontology—comprising the empirical, actual, and real—further enhances this perspective by encouraging leaders to analyze how visible events (the empirical) are shaped by systemic structures (the real) (Bhaskar, 1975b; Krauter, 2020b). In leadership contexts, entanglement suggests that decisions are not isolated acts but are part of broader relational dynamics influenced by both individual agency and structural forces.

For example, in the case of Markus Berger (5.4), retroductive reasoning revealed that his impostor syndrome and role ambiguity were entangled with systemic factors such as team dynamics and organizational culture. This understanding allowed him to address underlying issues through targeted interventions, such as clarifying team roles and fostering collaboration, ultimately enhancing his effectiveness as a leader. By using entanglement as a lens, leadership effectiveness can be redefined not as the outcome of individual traits but as the result of navigating interconnected relational systems (Lichtenstein & Plowman, 2009).

Incorporating Subjective Probabilities in Decision-Making

By interpreting subjective probabilities as a core aspect of leadership decision-making, this synthesis bridges CR's focus on causal powers with QSS's probabilistic view of reality (Fuchs, Mermin, & Schack, 2014; Haven & Khrennikov, 2013). Leaders often operate in environments where ambiguity prevails, requiring them to weigh multiple potential outcomes simultaneously. Unlike positivist paradigms that rely on deterministic models, the retroductive approach integrates subjective beliefs and evolving expectations, reflecting a more adaptive strategy for navigating uncertainty.

As illustrated in Markus's case, the application of subjective probabilities enabled him to evaluate feedback from his team as dynamic indicators of trust and morale. By prioritizing actions based on these probabilistic assessments, Markus was able to focus on interventions with the highest likelihood of improving team cohesion and performance. Such an approach aligns with the quantum principle of superposition, which allows leaders to consider multiple potential futures without prematurely committing to one path (Wendt, 2014).

This framework also highlights the coexistence of subjective agency and systemic causality within leadership. Leaders must navigate ambiguity by inferring the most likely successful paths based on dynamic, probabilistic assessments. For instance, in VUCA environments, leaders can use counterfactual thinking to explore "what-if" scenarios, enabling them to anticipate potential challenges and adapt strategies proactively (Vincent & O'Mahoney, 2018). The integration of retroductive inference and quantum principles thus empowers leaders to balance immediate demands with long-term systemic considerations.

Practical Implications and Benefits for Leadership Development

This synthesis offers actionable insights for leadership development, emphasizing the following benefits:

1) Improved Decision-Making: Leaders can uncover hidden causal mechanisms, enabling decisions informed by systemic dynamics and relational complexities (Mukumbang, Kabongo, & Eastwood, 2021). **Case Study Connection:** Markus used retroductive reasoning to analyze how clarifying team roles could reduce interpersonal conflicts and enhance trust, improving overall team performance.

2) Enhanced Adaptability: Retroductive inference equips leaders with the ability to navigate uncertainty by preparing for multiple scenarios, aligning with quantum principles such as superposition and entanglement (Krauter, 2020a). **Case Study Connection:** Markus balanced conflicting priorities during organizational transitions, iteratively recalibrating his strategies based on evolving team dynamics.

3) Conflict Resolution: By identifying and addressing systemic causes of conflict, leaders can foster sustainable solutions that strengthen team cohesion (Lichtenstein & Plowman, 2009). **Case Study Connection:** Markus addressed systemic issues underlying his team's misaligned goals, creating a shared vision that improved collaboration.

4) Strategic Alignment: Understanding leadership as relational and systemic ensures alignment between short-term actions and long-term objectives, enhancing organizational coherence (Kotter, 2012; Northouse, 2018). **Case Study Connection:** Markus reduced role ambiguity by aligning his team's tasks with broader organizational priorities, reinforcing both individual and collective accountability.

5) Development of Relational Competence: Leaders learn to view relationships as interdependent systems, leveraging entanglement to foster collaboration and shared vision (Haven & Khrennikov, 2013). **Case Study Connection:** In the

case of Markus Berger (5.4), his ability to recognize the interdependent nature of his relationships within the team was pivotal. Initially, Markus faced challenges in motivating his team due to a perceived lack of trust and mutual understanding. By focusing on building relational competence, Markus initiated team workshops designed to align individual goals with the collective vision of the organization. This effort not only improved interpersonal trust but also enhanced the overall performance and morale of the team, demonstrating the practical value of fostering entangled, collaborative relationships.

By combining retroductive reasoning with quantum principles, this framework equips leaders with the tools to navigate complex challenges while fostering adaptability, resilience, and systemic awareness. Furthermore, this synthesis provides a theoretical basis for future research, particularly in exploring how quantum-inspired methodologies can advance the study of leadership in dynamic organizational contexts.

4.3. Limitations

The emphasis on retroductive inference addresses some potential limitations by clarifying the framework's approach to causal explanation and the nature of quantum concepts in leadership.

Abstraction and the Application of Quantum Concepts

The integration of quantum principles into leadership, guided by retroductive reasoning, is a shift from metaphorical usage to a genuine ontological application. This intentional approach reduces the risk of abstraction and overgeneralization by treating quantum principles as real mechanisms within social reality rather than analogies. As such, the use of quantum concepts is not a limitation but a foundational assumption based on the belief that these principles genuinely exist within the four planes of social being (Bhaskar, 2009). This stance differentiates this synthesis from traditional social science paradigms, establishing it as a novel yet scientifically grounded approach.

Reconciling Probabilistic and Causal Perspectives

While QBism's subjective probabilities might initially seem at odds with CR's layered causality, retroductive inference bridges this gap by acknowledging that both subjective expectations and systemic conditions contribute to leadership phenomena. Rather than seeing probabilistic decision-making as conflicting with CR, we recognize it as complementary, as leaders must continuously infer and adapt their choices within a causal framework that is both subjective and relationally complex (Sayer, 2000). This synthesis respects both subjective agency and objective causal structures, representing them as parts of a unified framework rather than conflicting elements.

Need for Empirical Validation of Retroduction-Based Inferences

Although the framework provides a robust theoretical basis, empirical testing is essential to validate the inferred mechanisms and probabilistic assessments posited by this synthesis. Future research should design empirical studies that test

retroductively derived hypotheses, such as examining whether leaders' probabilistic approaches to decision-making correlate with improved adaptability in VUCA environments. Testing entanglement and superposition within team leadership contexts could empirically confirm whether these quantum concepts have practical effects on leadership outcomes, grounding the framework in observable phenomena while remaining true to its retroductive approach.

4.4. Implications for Future Research

The application of retroductive inference within a critical realist and quantum-inspired framework for leadership opens important avenues for future research, especially in exploring the causal mechanisms and unobservable structures that underpin leadership dynamics. Given the complex, multi-layered nature of leadership, future research should focus on empirically investigating the inferred mechanisms suggested through retroductive reasoning. Studies can utilize this approach to identify and test hidden structures and causal influences—such as relational networks, contextual factors, and psychological expectations—that drive observable leadership behaviors in complex, volatile environments.

A priority for future research is the empirical validation of these inferred mechanisms. For instance, through retroductive analysis, researchers can examine how concepts like quantum entanglement manifest in real-world leadership, particularly in team settings where the actions of one member influence others. Longitudinal and qualitative studies would be valuable for tracing the evolution of these entangled relationships and their impact on team dynamics over time. Additionally, the probabilistic nature of decision-making within this framework, driven by subjective beliefs and contextual adaptability, invites research into whether probabilistic reasoning genuinely enhances leaders' flexibility and resilience, particularly in VUCA (volatile, uncertain, complex, ambiguous) environments. By designing studies that assess leaders' adaptability in response to evolving probabilities and expectations, researchers could empirically test the benefits of probabilistic thinking for decision-making in unpredictable contexts.

Future research should also consider a multi-plane analysis of leadership, drawing from critical realism's four planes of social being—material, relational, structural, and personal. Retroductive inference allows researchers to examine how these planes interact to shape complex leadership phenomena, such as how material conditions (like organizational change) intersect with interpersonal dynamics (such as team cohesion) and subjective beliefs. By doing so, researchers can uncover the root causes of multi-dimensional leadership challenges, gaining a comprehensive understanding of how different layers of reality influence leadership outcomes.

Developing methodologies for empirically testing quantum-inspired constructs like superposition and interference in leadership offers another valuable area for future research. These concepts offer new ways of explaining leadership agility and decision-making under crisis conditions. Methodologies that experimentally

observe leaders' consideration of multiple strategic options (superposition) could reveal its effects on decision-making in high-stakes scenarios. Similarly, examining the impact of conflicting team feedback (interference) on leaders' ability to maintain cohesion and clarity under pressure could offer practical insights into the real-world implications of these quantum-inspired constructs.

Finally, advancing retroductive inference as a methodological tool in leadership research could benefit the field. As a method for uncovering hidden causal mechanisms, retroductive inference deserves further formalization and refinement. Researchers can contribute by developing standardized practices for hypothesizing and testing unobservable factors, demonstrating how retroductive inference complements other research methods, and setting best practices for applying this reasoning in leadership studies. Strengthening retroductive inference as a rigorous research tool can help provide richer, more nuanced theoretical insights into leadership and its underlying causal dynamics.

4.5. Limitations

The framework's integration of quantum concepts with critical realism offers a novel perspective on leadership; however, it faces several inherent challenges and boundaries. First, despite grounding quantum principles as ontological features within social reality, translating these ideas from quantum mechanics to social science remains complex. This complexity can lead to oversimplification or misinterpretation, especially when applied by researchers who may not fully grasp the depth of both disciplines (Haven & Khrennikov, 2013). Therefore, while this approach is theoretically robust, future research must carefully refine these principles to ensure they remain true to their quantum foundations within social contexts.

Additionally, empirical challenges arise when attempting to operationalize quantum concepts such as entanglement, superposition, and the Born rule in real-world studies. Leadership studies have traditionally relied on tools not designed to capture nuanced, subjective probabilities or systemic entanglement, and the development of new measurement tools may be necessary for effective empirical application. This difficulty presents a practical limitation to verification, which could limit broader acceptance until suitable tools are created.

Another important boundary is the potential misalignment with established research paradigms in social sciences. This framework departs significantly from traditional positivist and interpretivist approaches, which may lead to resistance when integrating with mainstream empirical methods in leadership research. Scholars grounded in conventional paradigms may struggle to reconcile the probabilistic and retroductive aspects of this framework with established models of causality in the field.

Furthermore, while retroductive inference allows for navigation between probabilistic and causal explanations, it introduces interpretive ambiguity. Retroduction is not a commonly used form of inference in leadership studies, which means

applying it can lead to subjective interpretations and potential inconsistencies in conclusions. For the framework to be consistently applied, future research will need to develop clear guidelines on how retroductive reasoning should function within this context, thereby upholding methodological rigor.

Finally, there is a boundary between the framework's ontological assumptions and its practical application. Assuming quantum principles as real within social contexts may not be universally accepted, particularly when researchers expect more directly observable outcomes. The challenge lies in demonstrating that these quantum-inspired concepts have real, tangible benefits in applied leadership contexts—such as improving decision-making or enhancing team dynamics—beyond their theoretical value. Showing observable and practical results from using these concepts will be essential for validating the framework's utility in applied settings.

5. Conclusion

The concluding chapter recaps the study's primary contributions, highlighting the key theoretical advancements made through the synthesis of quantum leadership, adaptive frameworks, and critical realism.

5.1. Summary of Key Contributions

This study fundamentally advances leadership theory by introducing a groundbreaking synthesis of critical realism (CR) and quantum principles, creating a dynamic, multi-layered framework that genuinely reflects the complexity of leadership in volatile, uncertain, complex, and ambiguous (VUCA) environments. Unlike traditional positivist approaches that rely on objective measurements and universal laws, this framework operates on the belief that quantum principles and CR-based causal mechanisms are real ontological aspects within social systems. This synthesis draws on concepts such as “fictional expectations” (Beckert, 2013), superposition, and entanglement from Quantum Social Science (QSS), providing a fresh, realistic understanding of leadership as a process continuously shaped by both subjective beliefs and systemic structures (Haven & Khrennikov, 2013; Wendt, 2014).

One key contribution of this study is its emphasis on temporal integration, capturing the active interaction between past experiences, present conditions, and future possibilities. Traditional leadership models, like those by Kotter (2012) and Northouse (2016), often isolate temporal aspects such as vision or influence but overlook how these timeframes dynamically interact. This synthesis bridges these gaps, framing leadership as a continuous process of adaptation that aligns with Beckert's (2013) notion of “fictional expectations,” where leaders draw from past insights and present realities to guide forward-thinking strategies. This temporal agility is essential in VUCA contexts, enabling leaders to respond dynamically to change and adapt to evolving conditions.

By grounding the framework in CR's multi-layered ontology, the study also extends leadership theory beyond simple cause-and-effect relationships, allowing

for a deeper exploration of the underlying structures that shape observable leadership behaviors (Bhaskar, 1975b; Kempster & Parry, 2011). Quantum-inspired concepts like superposition and entanglement are not used as metaphors but as actual principles within the social domain, enabling a nuanced understanding of how leaders navigate multiple roles and relational interdependencies in real time. This framework thus challenges deterministic models, providing a probabilistic view of decision-making that reflects the need for leaders to adapt based on ongoing changes. It aligns closely with Quantum Bayesianism's emphasis on subjective probabilities, portraying leadership as a fluid, context-sensitive, and relational process that genuinely mirrors the complexity of real-world organizational dynamics (Fuchs, 2023).

5.2. Final Thoughts

The synthesis of critical realism and quantum principles in this study underscores the importance of interdisciplinary integration for advancing theoretical and practical insights in leadership research. By bridging distinct paradigms, this framework not only addresses gaps in traditional leadership theories but also provides a foundation for future explorations. This innovative approach challenges researchers to move beyond conventional models, embracing the complexity, relationality, and context-specific nature of leadership as it exists in actual organizational settings.

Despite the study's contributions, it faces certain inherent challenges that future research must address. Reconciling tensions—such as QBism's subjective probabilities with CR's structural causality—requires further refinement to ensure that both subjective agency and systemic structures are accounted for in leadership. Future work should continue to explore how quantum principles apply ontologically within social phenomena, ensuring that these concepts are directly relevant and not prone to misinterpretation or overextension (Bhaskar, 1975a; Sayer, 2000).

Empirically, applying quantum-inspired principles in real-world leadership also calls for rigorous validation. While concepts like superposition and entanglement offer deep insights into leadership, the extent to which these principles manifest empirically in real-world environments remains to be explored. Empirical studies are essential for investigating whether probabilistic decision-making models inspired by Quantum Bayesianism genuinely enhance leaders' adaptability and resilience within VUCA settings (Fuchs, 2023). Such studies will be crucial in determining whether these probabilistic models improve organizational outcomes, thereby substantiating the practical value of this framework.

The study ultimately invites a shift in how leadership frameworks can evolve to better encompass the complexities of organizational life. By directly applying critical realism and quantum principles, the synthesis reveals the limitations of deterministic approaches and encourages leaders to view their roles through a genuinely relational and context-dependent lens. For practitioners, this perspective underscores that leadership is rarely straightforward; it requires constant recalibra-

tion, an understanding of interconnected social dynamics, and a readiness to adapt strategies to evolving situations. Leaders can use this framework to address complex challenges with greater flexibility, navigating uncertainty by continuously refining their approaches in response to new information and shifting social contexts.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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