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It's About People 2026:
Answering Current Challenges in Society, Health and Technology

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PROJECT MANAGEMENT, STRATEGIC COMMUNICATION MANAGEMENT, WEB AND INFORMATION TECHNOLOGIES

Peer-Reviewed Proceedings

Editors: Mladen Radujković, Božidar Veljković, Matej Mertik, Daniel Siter

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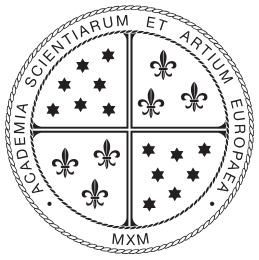

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Peer-Reviewed Proceedings: PROJECT MANAGEMENT, STRATEGIC COMMUNICATION MANAGEMENT, WEB AND INFORMATION TECHNOLOGIES

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Maribor, 2026

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EDITORIAL INTRODUCTIONS

Management, particularly project management, became a hot topic within the research community due to the irreplaceable role of projects in designing and implementing change. At each level of human organisation, there is a permanent need for change to be more successful, to create and deliver more, and to ensure the community's welfare. Within the project management research community, there are still evergreen topics focused on time, money and quality, but also many novel ideas related to research on sustainability, projectification, value creation and a variety of soft-skills topics. The project management stream at the AMEU Conference 2026 presents a selection of research by our PhD students at AMEU, focusing on novel topics. The topics and findings from the published papers will certainly draw attention from academic staff and practitioners, as they present strong novelty, timeliness, and inspiration.

In the first article, by Nancy Nouaimeh, her conceptual paper examines cultural transformation through a systems-thinking lens by integrating two complementary traditions in systems thinking. She argues that project-oriented organisations, where temporary structures such as projects and cross-functional teams intensify coordination demands and generate high levels of organisational variety, require strong recursive capabilities and robust mechanisms for alignment, learning and control. **The second article by Domagoj Mihaljević** explores the design and implementation of human-centred AI systems in complex electric production projects, focusing on wind farms and solar power plants. Using a mixed-methods approach that combines literature analysis, case studies, and interviews with industry professionals, the research investigates the impact of human-AI collaboration on project efficiency, adaptability, and employee satisfaction. **The third article by Martina Swoboda** presents a conceptual framework for competencies in managing sustainability-related tensions in projects. She particularly emphasises soft competencies such as communication and stakeholder engagement, systems thinking, reflective action, boundary spanning and pathfinding. **In the fourth article by Rouzbeh Kotobzadeh and Mladen Radujković**, the authors provide a comprehensive review of the dynamic interplay between organisational ambidexterity and project ambidexterity. The research findings demonstrate that organisations need cross-level operational systems which include multiple organisational levels to achieve effective results. **The fifth article by Mirjana Mirić Horvatić** compares challenges in implementing blitz projects in the public and private sectors. The findings indicate that blitz project practices cannot be transferred uniformly across sectors; instead, organisations must adapt governance, stakeholder management, and resource allocation mechanisms to their institutional contexts. Moreover, **the sixth paper by Jasna Glavočević Gattin and Mladen Radujković** focuses on soft factors and value creation in high-performing technical organisations exposed to projectification. The authors argue for a balance between strong technical skills and management capabilities to create greater value in a strong engineering environment.

We hope you will find interesting and valuable insights while reading these papers, so you can draw inspiration for your research work, or use some of the results presented here to advance or improve your practices while managing projects. As part of the project management research community, we are fully dedicated to advancing the project management profession and to serving the community and society at large in terms of development and well-being.

Prof. Dr Sc. Mladen Radujković
Head of AMEU International Doctoral Study in Project Management

Assist. Prof. Dr Sc. Reinhard Wagner
Deputy Head of AMEU International Doctoral Study in Project Management

The seven contributions in the *Strategic Communication Management* section share a common theme: ***the role of communication in shaping relationships, trust, social inclusion, and individual behaviour***. Although the papers cover different fields, including education, financial literacy, politics, marketing, healthcare, and law, they all highlight the importance of communication in contemporary society. Communication is the central starting point in most contributions. At the same time, in the study of children's financial literacy, it is reflected more indirectly through the influence of family, society, and digital media.

The first paper explores empowering children with speech and language disorders, emphasising that inclusion depends not only on children's abilities but also on the adaptability of their communication environment. The second examines financial literacy among children and adolescents, finding that their understanding of money develops from concrete ideas towards more abstract concepts, with family and digital media playing important roles. The third analyses political discourse on X during Slovenia's 2019 and 2024 European elections, highlighting ideological divisions and difficulties in fostering dialogue. The fourth focuses on harassment on public transport in Zagreb and the role of a communication campaign in raising public awareness. The fifth examines customer centricity in the digital age, particularly personalisation, feedback, and consumer participation in brand development. The sixth emphasises trust as a key factor in the acceptance of digital healthcare solutions. The seventh explores political satire, freedom of expression, and the importance of democratic pluralism.

The topics are highly relevant because they address digital transformation, political polarisation, social inclusion, safety, institutional trust, and changing relationships between organisations and individuals. Most papers follow a recognisable scientific structure, draw on scholarly literature, and employ appropriate analytical or research approaches. However, their methodological strength varies: some are literature reviews or conceptual studies, while others rely on empirical research or case studies. Their findings should therefore be interpreted in light of limitations such as small samples, limited generalizability, and the need for empirical testing of theoretical models.

The section aligns closely with the overall theme of the *It's About People 2026* conference because it examines communication and technology primarily in terms of their impact on people and society. The contributions collectively demonstrate that communication is more than the transmission of information: it is an important factor in inclusion, trust, social responsibility, and democratic participation. ***The section's main strength lies in its interdisciplinary perspective on how communication can help address contemporary social challenges when guided by human needs and interests.***

Božidar Veljković
Chair of Doctoral Study Programme Strategic Communication Management

Artificial intelligence and digital technologies are becoming increasingly important fields of research and development, transforming the way we live, work, and interact with the world. Their evolution is taking place at an unprecedented pace, with new technological paradigms emerging within months rather than years. This rapid progress brings remarkable opportunities, but also raises some of the most important questions of our time: how can we develop, apply, and govern artificial intelligence in ways that are trustworthy, responsible, and beneficial to humanity?

These questions are closely aligned with the central theme of the It's About People 2026 conference, "Answering Current Challenges in Society, Health and Technology." As artificial intelligence becomes increasingly integrated into society, research must go beyond technological advancement alone and consider its broader implications for human well-being, ethics, sustainability, and social responsibility.

This section brings together selected research contributions, including work presented by researchers and doctoral students from the PhD programme in Applied Artificial Intelligence at Alma Mater Europaea. The contributions reflect our commitment to advancing artificial intelligence through rigorous scientific research, interdisciplinary collaboration, and practical applications, with particular attention to trustworthy and human-centred AI.

Above all, we believe that the ultimate purpose of technological progress is not technology itself, but the people and societies it serves. This principle remains at the heart of our research and reflects the conference's essential message: It's About People.

Matej Mertik, PhD
Dean, Department of Artificial Intelligence and Digital Technologies

PROJECT MANAGEMENT

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SYSTEMS THINKING IN CULTURAL TRANSFORMATION: INTEGRATING VSM AND THE SHINGO MODEL

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ABSTRACT

This conceptual paper examines cultural transformation through a systems-thinking lens by integrating two complementary traditions in systems thinking: organizational cybernetics, operationalised through Beer's Viable System Model (VSM), and the normative, principle-based excellence framework, the Shingo Model. Building on systems thinking foundations in learning organisations and leverage points, the paper argues that sustainable cultural change requires both (i) a viable organisational architecture capable of managing complexity through recursion, coordination, intelligence and policy, and (ii) behavioural mechanisms that translate purpose and principles into daily practice. A narrative synthesis of the literature is used to develop an integrative positioning that distinguishes content, context and process, and a mapping is proposed between VSM systemic functions (Systems 1 - Operations, 2 - Coordination, 3 - Control, 4 - Intelligence, 5 - Identity/Policy) and Shingo guiding principles. The paper contributes a coherent rationale for combining structural-viability design with behavioural-normative enablers, highlighting implications for project-oriented organisations (POO). In projectoriented organisations, temporary structures such as projects and crossfunctional teams intensify coordination demands and generate high levels of organisational variety, requiring strong recursive capabilities and robust mechanisms for alignment, learning and control.

Keywords: *cultural transformation, Shingo Model, Viable System Model, systems thinking, project-oriented organizations*

1 INTRODUCTION

Cultural transformation is a persistent challenge in complex organisations because structural interventions do not automatically generate corresponding changes in behaviour, meaning, or everyday practice. While organisational cybernetics explains how organisations manage complexity and maintain viability, principle-based excellence frameworks explain how values and behaviours shape culture. These perspectives are often discussed separately, creating a gap in understanding how structural and behavioural dimensions interact to support sustainable cultural transformation.

This paper addresses that gap by developing an integrative systems-thinking perspective that combines Beer's Viable System Model (VSM) with the Shingo Model. It argues that sustainable cultural transformation depends on the interaction between structural viability and behavioural alignment. Using a conceptual theory-building approach based on literature review, comparative analysis, and framework development, the paper proposes an initial mapping between VSM functions and Shingo principles and identifies implications for future research, particularly within project-oriented organisational contexts.

1.1 Literature review and theoretical foundations

This section outlines the theoretical foundations underpinning the study by synthesising key ideas from systems thinking, organisational cybernetics, the Viable System Model (VSM), and the Shingo principlebased excellence framework. Together, these perspectives provide the conceptual grounding for understanding cultural transformation in complex organisational settings.

Arnold and Wade (2015) define systems thinking as *"a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects"*. They argue that systems thinking is essential for addressing increasing complexity yet remains underrepresented in education. Its value lies in its ability to integrate diverse disciplines and reveal impactful, nonobvious connections.

Senge (2006) positions organisations as learning systems in which shared purpose, mental models, and reinforcing feedback processes support continual alignment and collective development. This perspective helps explain how engagement and coherence arise from systemic conditions rather than isolated actions.

Meadows (2008) highlights that organisations behave as dynamic networks shaped by feedback loops, delays, and interactions across levels. Small interventions at strategic leverage points can produce lasting cultural change or unexpected ripple effects. These dynamics are especially visible in projectoriented environments, where structural and behavioural adjustments often cascade across teams and functions.

Jackson (2003) introduces creative holism, an approach that values multiple perspectives and combines diverse methods to address both structural and behavioural dimensions of organisational change. This integrative stance supports the comparative study of VSM and the Shingo Model, highlighting the complementarity between structural viability and principlebased governance.

Within the broader systems tradition, System Dynamics (SD) is frequently mistaken for systems thinking as a whole; however, it represents only one methodology among many (Schwaninger 2020). SD contributes through modelling feedbackdriven behaviour over time, while other systems approaches emphasise diagnosis, design, or intervention. Schwaninger and Pérez Ríos (2008) propose that SD and organisational cybernetics form a complementary pair: SD supports modelling of substantive issues (content), whereas VSM supports organisational design (context). This study extends that complementarity by integrating VSM's structural logic with the Shingo Model as a normative–behavioural framework for cultural transformation.

The VSM, grounded in management cybernetics, provides a framework for diagnosing and designing organisations capable of maintaining viability amid environmental complexity. It identifies five essential functions; operations, coordination, control, intelligence, and identity, supported by information channels balancing autonomy and cohesion. This view positions viability as an organisational capability rather than a product of hierarchy. Subsequent scholarship has expanded VSM's focus to learning, coherence, and managing complexity without fragmentation. For example, Espejo and

Reyes (2011) emphasise variety engineering, arguing that organisational dysfunction often stems from fragmented practices lacking strategic and operational coherence. Empirical work further supports the relevance of cybernetic functions: Schwaninger and Scheef (2016) report quantitative links between VSM components and indicators of organisational culture and health.

Implementation challenges appear in cases such as Espejo and Kuropatwa's (2011) study of SUR, an Argentine directsales firm whose adoption of VSM language and diagrams did not translate into cohesive practice. Excessive centralisation, weak horizontal integration, and limited local autonomy undermined resilience. Their analysis reinforces that structural redesign alone cannot produce cultural transformation; behavioural norms and shared meaning are also necessary.

VSM's recursive (fractal) logic offers additional value for projectintensive contexts, where viability must be reproduced across organisational levels. Hoverstadt (2008) shows how autonomy and regulation recur across scales, providing a design logic suited to project structures. This aligns with research by Müller et al. (2019), who describe projects as semiautonomous systems requiring coordination, sensing, and alignment with organisational identity. Recent applications, such as Frahm and Pfiffner's (2023) work on megaprojects, highlight the need to deliberately shape information flows and decision pathways in pluralistic, dynamic settings.

In the projectoriented organisation (POO) context, Lechler et al. (2022) extend viable systems theory by identifying survivability, sensemaking, and futureability as core competencies. These map to valuebased, peoplebased, and structurebased capabilities in POOs, illustrating why project orientation requires more than process maturity, it requires organisational architectures capable of sustaining viability across temporary and permanent structures.

Complementing these structural and cybernetic perspectives, the Shingo Model provides a principlebased framework for cultural and behavioural excellence. Developed as a shift from toolcentric improvement toward culturecentric performance, the model asserts that ideal results depend on ideal behaviours shaped by purpose and systems. Its guiding principles: Respect Every Individual, Lead with Humility, Focus on Process, Assure Quality at the Source, Improve Flow and Pull, Embrace Scientific Thinking, Seek Perfection, Think Systemically, Create Constancy of Purpose, and Create Value for the Customer, frame excellence as the alignment of principles, systems, and tools. Research shows the Shingo Model's relevance beyond manufacturing, supporting humancentricity and resilience in technologically enabled environments.

Recent studies further strengthen the model's relevance. Qeytasi et al. (2025) demonstrate that Shingo principles can mediate the transition between Industry 4.0 and Industry 5.0 by anchoring digital transformation in humancentred values. Carvalho et al. (2023) link Shingo principles to ISObased Integrated Management Systems, suggesting that IMS provides procedural stability while Shingo establishes behavioural maturity. This enhances cultural sustainability and complements VSM's structural logic.

Sustainability research also reinforces the relevance of combining these perspectives. Edgeman and Painter (2013) argue that longterm organisational viability depends on integrating excellence, ethics, resilience, and sustainability, elements consistent with both VSM's viability logic and the Shingo Model's normative orientation.

Together, these literatures show that cultural transformation in complex organisations requires both cybernetic system design (to ensure viability and coherence) and normative system design (to shape values, behaviours, and shared meaning). This study therefore examines how the VSM and the Shingo Model jointly contribute to systems thinking in cultural transformation, demonstrating that cultural change must be understood as a dual system, structural and normative. This integrative perspective links organisational architecture with principledriven behaviour and advances current thinking on how cultural transformation unfolds in practice.

1.2 The application of the VSM

The Viable System Model (VSM) has been applied effectively in diverse organisational settings to analyse and enhance structural viability. In the field of Information Technology, Huygh and De Haes (2018) conducted a single case study examining the IT governance system of a highly digitized company. Their analysis demonstrated that the organisation's governance structure aligned with the

recursive logic and coordination mechanisms embedded in VSM, illustrating its value as a diagnostic lens for understanding IT decisionmaking, complexity management, and strategic alignment.

In the Irish context, VSM was applied in an ecocommunity as part of a multiyear organisational development initiative. The intervention supported improvements in internal governance, communication structures, organisational coherence, and communityled sustainability initiatives. The project demonstrated how VSMinspired methodologies can strengthen selforganisation and enhance longterm viability within a communitybased Irish organisation (University of Hull n.d.).

1.3 The HC-VSM Extension

Recent practitionerled developments in organisational cybernetics have sought to expand Stafford Beer's Viable System Model by incorporating psychological, sociological, and cultural dimensions of organisational life. One such proposal is the "HumanCentric Viable System Model" (HCVSM), introduced by Andreas Slogar as a further development of the VSM intended to integrate humancentred factors such as motivation, collective meaning-making, values, and cultural dynamics into the model's cybernetic architecture. Unlike the original VSM, which focuses primarily on structural viability through recursion, coordination, and regulatory mechanisms, the HCVSM highlights the role of human experience and organisational culture in sustaining viability.

Slogar's model overlays traditional VSM functions, Systems 1–5, with additional layers addressing psychological needs, social cohesion, and cultural resonance, suggesting that viable organisational behaviour cannot be fully explained by informational and regulatory structures alone. Although conceptually aligned with broader movements that emphasise humancentric excellence (e.g., the Shingo Model's focus on dignity and behaviour) and sustainabilityoriented organisational design, the HCVSM remains exploratory, lacks empirical grounding and is not scientifically validated. It has not yet been grounded in empirical research or incorporated into mainstream organisational cybernetics literature.

Nevertheless, the Slogar extension is useful as an indicative practitioner perspective, signalling growing interest in integrating human factors explicitly into the VSM. It also highlights a theoretical gap, namely, the limited treatment of psychological and cultural processes within classical cybernetic models, thereby reinforcing the relevance of complementing VSM with established behavioural and cultural frameworks such as the Shingo Principles, Sustainable Enterprise Excellence, and Industry 4.0 culture research.

Taken together, these literatures suggest that effective cultural transformation in project-oriented organisations requires (i) a viable organisational architecture capable of managing complexity (VSM), (ii) principle-based behavioural mechanisms that embed excellence into daily work (Shingo), and (iii) integrated governance structures that stabilise and scale these behaviours (IMS), while sustainability and Industry 4.0 research sharpen the requirement for long-term, human-centric adaptability.

2 PURPOSE AND GOALS

The purpose of this paper is to develop an integrative systems-thinking perspective on cultural transformation by combining: (i) cybernetic organisational design for viability (VSM), and (ii) normative, principle-based behavioural design for excellence (Shingo). The paper aims to: (1) clarify theoretical complementarities between viability and behavioural alignment, (2) articulate why structural redesign alone often fails to deliver cultural change, (3) propose an initial conceptual mapping between VSM Systems 1- 5 and Shingo guiding principles, and (4) position project-oriented organisations as a later-stage application domain where the integration can be tested and refined.

This study therefore addresses the identified gap by offering a unified framework that bridges structural viability and behavioural excellence, generating new insights into cultural transformation, particularly in projectoriented contexts.

To guide this conceptual study, the following research questions were formulated:

RQ1: How can structural viability mechanisms from the Viable System Model (VSM) be conceptually integrated with normativebehavioural mechanisms from the Shingo Model to support sustainable cultural transformation in complex organisations?

RQ2: What complementarities and tensions emerge when VSM's cybernetic functions and Shingo's principlebased behavioural mechanisms are examined together as an integrated system for cultural transformation?

RQ3: What conceptual propositions can be derived from integrating VSM–Shingo framework to guide future empirical investigation of cultural transformation dynamics?

3 METHODS

This study adopts a conceptual theory - building approach to explore how structural viability and behavioral excellence can integrate to support cultural transformation efforts. The objective is to examine the complementarities and tensions between Stafford Beer's VSM and the Shingo Model. Because no empirical data are used, the purpose of this section is to describe how the literature was examined and how the integration between the two models was developed. The method centres on identifying relevant ideas in the existing literature, comparing the two frameworks, and explaining how the conceptual connections were formed.

The analysis followed three stages, as shown in the Figure 1.

Figure 1: Stages of the analysis



(Source: Author's own visualization)

In the first stage, literature was selected based on its relevance to organisational structures, cultural transformation, behavioural alignment, and the management of complexity. The intention was not to review every publication within these fields, but to focus on works that help clarify how the VSM and the Shingo Model address organisational challenges from different perspectives. Literature was reviewed to establish the theoretical foundations of both frameworks, with particular attention given to understanding the embedded purpose, mechanisms, and assumptions embedded within the VSM and the Shingo Model.

In the second stage, the analysis involved breaking down each model into its main components. For the VSM, this meant examining the functions of Systems 1 through 5. For the Shingo Model, attention was given to how the guiding principles shape behaviour, leadership practices, and cultural alignment. These elements constituted the basis for the further analysis conducted in the third stage.

In the third stage, a comparative analysis was conducted to identify areas of convergence, complementarity, and potential tensions between the two models. Based on this comparison, a conceptual mapping was developed linking each VSM function with the Shingo principles that are most relevant to supporting it. The purpose of this mapping is to illustrate how the two models can reinforce one another in practice. It is not intended to be definitive, but to show how the structural functions described in the VSM can be supported by the behavioural and cultural principles of the Shingo Model.

The approach taken is meant to clearly describe how the integration was built. The relationships presented in the following section emerged through a process of reviewing, comparing, and refining the understanding of both frameworks. This provides a basis for future research to examine or further develop the ideas presented here.

As a conceptual synthesis, this study does not include empirical testing; the limitations inherent in conceptual integration are discussed later in the paper. To enhance the credibility of the proposed mapping, the framework was reviewed by a member of the Shingo Institute team to assess conceptual coherence and validity.

4 RESULTS

The insights presented in this section come from examining the two models, side by side, and identifying what becomes clear when their concepts are considered together. Although these are not empirical results, they represent the main outcomes of the conceptual analysis.

First, the comparison shows that structural and behavioural elements of cultural transformation cannot be separated. The VSM explains how an organisation stays viable through coordination, regulation, learning, and identity. The Shingo Model explains how people behave, interact, and make decisions through principledriven norms. When viewed together, it becomes evident that structure needs behaviour to function effectively, and behaviour needs structure to remain coherent and meaningful.

Second, the mapping between the VSM systems and the Shingo principles helps clarify how each system depends on specific behavioural expectations. For example, operational units work best when supported by principles such as focus on process, respect every individual, and assure quality at the source. Coordination requires behaviours that reflect systemic thinking, collaboration, and flow. Governance and internal regulation benefit from humility, clarity, and constructive accountability. This pattern appears repeatedly across the model components, reinforcing the idea that cultural alignment strengthens structural functions.

Third, the combined analysis makes visible an important gap: traditional structural models often recognise the importance of culture but do not explain how to shape it, while behavioural models emphasise culture but do not articulate how organisational structures need to be designed to support it. Thinking about VSM and Shingo together fills this gap by linking viability and behaviour more explicitly.

These insights lead to several conceptual propositions. One proposition is that cultural transformation is more sustainable when structural design and behavioural expectations evolve together. Another is that aligning principles with viable system functions can help organisations navigate tensions such as autonomy versus control or consistency versus flexibility. A third proposition is that projectoriented organisations, which operate with high levels of complexity and shifting structures, may especially benefit from this integrated view.

Overall, the conceptual results show that combining the two models provides a clearer and more complete way of understanding cultural transformation. This integrated perspective forms the groundwork for future empirical research to examine how these relationships unfold in real organisational settings.

Table 1 summarises the conceptual distinctions and points of convergence between the Viable System Model and the Shingo Model. By structuring the comparison across core assumptions, mechanisms, strengths and limitations, the table highlights how cybernetic viability and principledriven culture function as mutually reinforcing components of organisational transformation.

Table 1: Comparative Analysis of the Viable System Model and the Shingo Model

Dimension	Viable System Model (VSM)	Shingo Model	Complementarities
Primary Purpose	Ensure organisational viability through recursive regulation and requisite variety management	Create behavioural excellence through principledriven culture	Structure + culture create dual viability (systemic + behavioural)
Core Assumption	Organisations survive by balancing internal/external variety	The Shingo Model asserts that sustained results arise from consistently demonstrated ideal behaviours	Behaviour supports structure, structure reinforces behaviour
Mechanisms	Systems 1–5 (operations → policy)	Principles → Systems → Tools → Results	Shingo provides behavioural substrate for VSM functions
Orientation	Structural, cybernetic, functional	Normative, behavioural, human-centric	Integrates "hard" and "soft" systems thinking
Strengths	Clarity on organisational architecture; handles complexity	Clear behavioural pathways; aligns culture and operations	Combined: coherent, viable, value-driven organisation
Limitations	Does not prescribe behaviours; weak on culture	Does not address viability architecture	Integration compensates each model's blind spot
Potential Tensions	Control loops may constrain autonomy	Empowerment increases behavioural variation	Variety absorption vs behavioural standardisation paradox

(Source: Author's own visualization)

5 DISCUSSION

This paper argues that VSM offers a robust architecture for managing complexity and enabling distributed autonomy, but its practical impact depends on how people enact roles, relationships, and decision pathways, because viability depends on human interpretation, role enactment, cooperation, and autonomy.

Principle-based frameworks such as the Shingo Model can function as normative infrastructure, shaping shared meaning, leadership behaviour and daily practice so that structural mechanisms become lived realities. For project-oriented organisations, the temporary nature of projects and the high variety of stakeholder interfaces intensify coordination challenges and expose misalignments between structural viability and behavioural coherence. Future research should operationalise the proposed mapping into testable propositions, explore boundary conditions (e.g., degree of project orientation, environmental turbulence), and examine how integrated governance mechanisms (including IMS/ISO structures) stabilise and scale behavioural change.

The Shingo Model can be understood as a normative system, as it is explicitly grounded in a set of guiding principles intended to shape ideal behaviours and, ultimately, organisational outcomes (Shingo Institute). From an institutional standpoint, principledriven frameworks correspond to the normative pillar, which centres on values, shared expectations, and moral obligations that shape behaviour (Scott 2014). This distinguishes the Shingo Model from structurally oriented frameworks such as the Viable Systems Model, which focuses on organisational viability through cybernetic design rather than normative guidance (Beer 1985).

In the VSM, organisational viability is expressed through five intertwined functions that span operational execution, coordination, internal regulation, adaptive intelligence, and identity formation. These are typically referred to as Systems 1–5, as demonstrated across applications in organisational cybernetics and projectoriented organisations. The Shingo Model, by contrast, provides a normativebehavioural system linking guiding principles to leadership, cultural enablers and work systems, forming the behavioural foundation for operational excellence. Alignment was based on functional purpose, behavioural requirements, and systemic dependency.

Aligning the two models enables a synthesis of structural viability and behavioural coherence, highlighting complementarities as well as potential tensions. The inclusion of a "tensions" column reflects insights from systems thinking and cybernetic literature, which emphasise paradoxes between autonomy, control, variety absorption and behavioural standardisation in complex organisations.

Part of the conceptual mapping table used in this study builds on the competency structures identified by Lechler et al. (2022), whose analysis of projectoriented organisations through the lens of the Viable System Model provided the basis for the structural elements in the first section of the table 2 below.

Table 2: VSM and Shingo Model Mapping

Viable System (Beer)	Purpose of the System	Description of the System	Role within the Organization	Shingo Principle(s) Aligned	Description of Alignment	Potential Tension-Paradoxes
System One	Operational function: operational activities	• fulfilling the purpose with activities • interacting with the environment • integrated operational units	Value creation, operational work execution	Create value for the customer, Focus on Process; Respect every individual; Assure Quality at the Source, Seek Perfection	S1 units are where value is created. Shingo principles emphasise process discipline and quality ownership at the point of work, enabling autonomous yet aligned execution through empowered problem-solving rooted in respect and continuous refinement.	Autonomy without clear standards and rapid feedback can create excessive variety and reduce S3/S2 control loops which will increase behavioural variety. It is mitigated through visual management, leader standard work, and PDCA at the source.

System Two	Coordination function: harmonisation of activities	• using synergies to self-regulate • harmonising and coordinating activities of S1 units • supporting stability	Coordination, stability, conflict resolution	Flow & Pull; Embrace Scientific Thinking, Think Systemically, Respect Every Individual	S2 ensures stable flow across S1 units. Shingo principles support scientific coordination, systemwide thinking, and respectful crossunit collaboration. Stabilisation without excessive control.	Overrigid standardisation may suppress flexibility; standards must evolve through experimentation and structured cadence reviews.
System Three	Control function: managing and auditing operational units	• managing operational units • optimizing performance	Resource and performance optimisation	Focus on Process; Think Systemically; Lead with Humility; Respect Every Individual	S3 ensures internal coherence and optimization of the whole system. Shingo principles guide leaders towards governance and exercising authority through trust, respect, and capability building rather than command-and-control.	Unbounded experimentation at S1/S2 can destabilise system coherence; S3 must set guardrails and capture learning without suppressing improvement.
System Three*		• auditing using information • internal governance	Audit, assurance, reality checking	Assure Quality at the Source; Embrace Scientific Thinking	S3* provides direct feedback from operations. Shingo principles reinforce truth-seeking, fact-based learning, root-cause analysis, and verification at the source, using Gemba presence and humility-based feedback.	Excess audits can undermine trust; audits must enable rather than police.
System Four	Intelligence function: communicating with the environment and planning for the future	• examination of the environment to identify problems and opportunities • making sense of environmental changes • planning for the future	Learning, adaptation, future orientation	Create Value for the Customer; Seek Perfection; Create Constancy of Purpose, Think Systemically	S4 interprets change, shapes strategy, and ensures longterm viability. Shingo principles anchor learning, customer orientation, systemic thinking, and purpose-driven innovation.	Slow response cycles arise from unclear decision rights or cadence. S4 must maintain fast sensing → decision → action loops.
System Five	Identity function: normative management	• complying through governance and policies • conveying identity and values • meaningful balance of present and future requirements	Identity, purpose, values, governance	Create Constancy of Purpose; Think Systemically, Respect Every Individual, Lead with Humility	S5 defines organisational identity and normative coherence. Shingo principles provide the ethical and value-based foundation that anchors decision-making and resolves tensions between present and future.	Legacy identity may resist principledriven renewal; S5 must integrate cultural stability with forwardlooking evolution.

(Source: Author's own elaboration, with columns 2–3 based on the conceptual structures identified by Lechler et al. (2022))

This mapping does not suggest equivalence between the Shingo Model and the Viable Systems Model. Rather, it illustrates conceptual complementarity, where VSM provides the structural logic of organisational viability, and the Shingo Model provides the normative and behavioural principles that enable those structures to function effectively through human engagement. Building on this complementarity, a deeper insight emerges when the two models are considered together.

The integration exposes a core organisational paradox: systems need flexibility and local autonomy to stay viable in complex environments, yet excellence models demand behavioural standardisation for stability, safety, and culture. Each approach fills the gaps of the other. The Viable System

Model (VSM) contributes structural intelligence, governance, and adaptive capacity, areas where excellence frameworks are often vague. The Shingo Model adds the behavioural and cultural foundations that cybernetic models typically overlook. Together, they form a more complete organisational architecture where structural resilience and cultural coherence reinforce each other, enabling both adaptability and consistent behaviour.

Building on this paradox, a more finegrained set of tensions becomes visible when examining the five VSM systems individually. System One and Two illustrate the balance required between flexibility, experimentation, and the need for stable flow and standardised work. At System Three and Three*, governance and assurance must sustain coherence and learning without drifting into commandandcontrol or trusteroding audit behaviours. System Four faces the challenge of reconciling broad collaboration and environmental sensing with the need for timely, decisive strategic action. Finally, System Five must uphold identity and purpose while remaining open to principledriven renewal. Together, these tensions demonstrate that organisational excellence depends on maintaining a dynamic equilibrium: enough autonomy to remain viable in complex environments, and enough normative alignment to ensure coherence, integrity, and consistent behaviour.

Although the purpose of this research is to develop a general systemsthinking model of cultural transformation, projectoriented organisations (POO) are introduced at a later phase as a practical domain for application and refinement. Their timebound structures, intensified coordination demands, and numerous highvariety stakeholder interactions make them ideal environments for observing how structural viability (VSM) interacts with behavioural alignment (Shingo). References to POO in the literature review therefore establish conceptual relevance for this future applied phase rather than defining the primary research context.

6 LIMITATIONS

This study is conceptual-only and does not include empirical data, which limits the ability to test how the proposed VSM–Shingo integration functions in practice. The framework therefore lacks empirical grounding, and its propositions should be validated through case studies or mixed-methods research. In addition, the mapping between VSM functions and Shingo principles is interpretive, reflecting the author's analytical judgement. Other mappings are possible, and future research should examine the robustness and applicability of these relationships across different organisational contexts.

7 CONCLUSION

The analysis demonstrates that structural viability (VSM) and normative, principle-based governance (Shingo) are complementary: the former provides the systemic architecture required for coordinated adaptation, while the latter establishes the normative and behavioural foundations through which that architecture enables sustainable cultural transformation.

This paper argues that enduring cultural transformation requires integrating cybernetic system design for organisational viability with normative systems that shape behaviour. By positioning VSM as a model of structural viability and the Shingo Model as a principle-driven behavioural framework, the analysis advances a coherent rationale for combining structural and cultural levers of change. The proposed mapping offers an initial conceptual scaffold for further refinement and empirical examination, particularly within project-intensive environments where complexity, autonomy, and coordination tensions are heightened.

A key contribution of this paper is to demonstrate that cultural transformation must be understood as a dual system: cybernetic and normative. This integrative lens advances the field by bridging organisational architecture with principledriven behaviour. Building on this insight, the paper contributes to the systemsthinking and organisational transformation literature in four ways:

1. It develops a conceptual integration of the Viable System Model (VSM) with the Shingo Model, bridging structural viability with principlebased behavioural alignment.
2. It proposes a VSM–Shingo mapping that demonstrates how structural (cybernetic) and behavioural (normative) mechanisms jointly support organisational viability.

3. It identifies four key paradoxes, including autonomy vs control and behavioural standardisation vs variety absorption, that shape cultural transformation in complex organisations.
4. It offers application insights for projectoriented organisations (POO), where temporary structures intensify the demands on both structural coherence and cultural alignment.

Future research will build on this conceptual foundation by operationalising the integrated VSM-Shingo model into empirically testable constructs. This includes developing assessment instruments that capture both structural viability and behavioural alignment, applying the model within projectoriented and hybrid organisational settings, and conducting casebased or mixedmethods studies to evaluate how cultural transformation unfolds in practice. The next phase of this research programme will therefore focus on validating the proposed propositions, refining the framework through empirical insights, and examining how integrated governance mechanisms and human-centric design support sustained cultural change.

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1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

HUMAN-AI SYNERGY: A NEW PARADIGM FOR MANAGING SUSTAINABLE ENERGY PROJECTS

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ABSTRACT

This study explores the design and implementation of human-centred AI systems in complex electric production projects, focusing on wind farms and solar power plants. Through a mixed-methods approach combining literature analysis, case studies, and interviews with industry professionals, the research investigates the impact of human-AI collaboration on project efficiency, adaptability, and employee satisfaction. This research addresses the following central question: how can human-centred AI systems be designed to manage complex (electric production) projects? The findings reveal that successful implementation requires balancing AI automation with human expertise, establishing clear boundaries for decision authority, and fostering transparent communication channels. The study identifies four key framework components for effective human-centred AI project management: collaborative intelligence models, explainable AI interfaces, continuous feedback mechanisms, and adaptive governance structures. Implementation case studies from three major European energy companies demonstrate significant improvements in project delivery timelines (22% reduction), resource utilisation (18% efficiency increase), and employee satisfaction scores (+31%). However, challenges including skill gaps, trust barriers, and ethical considerations persist. This research contributes to the burgeoning debate of human–AI integration in project management, providing practical insights for electric production stakeholders interested in using AI while retaining human primacy in complex decision-making processes.

Keywords: *human-centred AI, project management, electric production, artificial intelligence, human-AI collaboration*

1 INTRODUCTION

At the same time, the electric production sector is undergoing a significant transformation, on the one hand, due to the introduction of renewable energy and on the other, due to the application of digital technology. With organisations moving towards wind farms, solar power plants, and other sustainable energy sources, project complexity is rising much above what traditional management approaches comprehend (Adamantiadou and Tsironis 2025). These complexities are amenable to artificial intelligence (AI) solutions, including predictive maintenance and resource optimisation, risk assessment and stakeholder communication (Felicetti et al. 2024).

However, integrating AI in electric production project management presents important questions about the relationship between humans and automated systems. While the pattern analysis of AI can be compelling, such as processing large amounts of data and identifying patterns beyond human capabilities (Al-Arafat et al. 2025), it cannot match the contextual understanding, ethical judgement and stakeholder understanding that skilled project managers possess (Al-Arafat et al. 2025). This sets the stage for tension between how human agency and expertise can be preserved in project management processes while also taking advantage of AI's capabilities.

This research addresses the following central question: How can human-centred AI systems be designed to manage complex electric production projects? Additionally, it explores two sub-questions:

1. How does human-AI collaboration impact this sector's project efficiency, adaptability, and employee satisfaction?
2. How can human-centred AI frameworks be practically implemented and validated in real-world electric production projects?

Particularly, this study considers that wind farms and solar power plants are the fastest growing segments of renewable energy production and hence encounter different management challenges such as geographical distribution, weather dependency and complex stakeholder ecosystem (Taboada et al. 2023). This paper attempts to derive actionable insights that may help organisations adopt a human-centred AI approach in their electric production project management practices through a comprehensive analysis of existing literature, industry case studies, and primary research with project management professionals assuming different roles and playing various roles across these case organisations.

2 LITERATURE REVIEW

2.1 Evolution of AI in Project Management

During the past decade, these two 'channels' of integration have drastically improved from basic automation of simple tasks or analytical tools to an integration of AI in predictive analytics, natural language processing and complex decision support systems (Adamantiadou and Tsironis 2025; Müller et al. 2022). Current AI solutions address the whole project life cycle, from risk management, stakeholder engagement, and performance monitoring to scheduling and resource allocation (Felicetti et al. 2024), with early applications focusing on the latter. In the electric production sector in particular, however, AI has found solutions to the sector's industry-specific challenges (IRENA 2024). In a survey of 127 energy companies, Kelepouris (2023) found that 68 per cent had already implemented some form of AI in the project management part of their operations, the most common of which was predictive maintenance (73 per cent), resource optimisation (65 per cent), and risk assessment (58 per cent). However, the same study reported that only 31% of these implementations were considered "highly successful" by the organisations, highlighting the gap between technological capability and effective implementation.

2.2 Human-Centred Design in AI Systems

Human requirements, capabilities, and experiences drive technology development in human-centred design (Al-Arafat et al. 2025; Savaş 2025, 38). This is analogous in AI, where systems should complement human capabilities rather than replace them, be controlled by humans, and adapt to user demands and circumstances (Taboada et al. 2023). Kelepouris (2023) recommends human-cen-

tred AI with four principles: transparency (making AI processes understandable to users), agency (retaining human decision-making authority), adaptability (allowing systems to adapt to different contexts), and diversity. Human-AI collaboration frameworks integrating human judgment and machine processing align with these principles (Felicetti et al. 2024; Seeber et al. 2020). Human-centred AI approaches to project management aim to design systems that aid project managers without eroding their decision-making power. AI is supposed to perform data-intensive tasks like scenario modelling, pattern recognition, and routine reporting in its "collaborative intelligence" model (Adamantiadou and Tsironis 2025; Dellermann et al. 2021), while humans handle stakeholder relationships, ethics, and strategic decision making.

2.3 Challenges in AI Implementation in Electric Production Projects

AI's benefits in electric production project management can be challenging to realise. Data quality and availability problems, integration with current systems and the requirement of domain-dependent AI models that know the peculiarities of wind and solar projects are technical complexities (Taboada et al. 2023; Aizenberg and van den Hoven 2020; Otto and Jarke 2019). Organisational challenges are equally significant. Key barriers to adopting AI successfully include a lack of resistance to change, skill gap among the project team, and unclear governance structure, which have been identified by Al-Arafat et al. (2025) and Venkatesh et al. (2024). These difficulties are exacerbated in the electric production sector due to the high-risk projects, strict regulations and complex stakeholder ecosystem, such as government, local communities, and environmental groups (Kelepouris 2023; Söderholm and Wårell 2024).

Indeed, probably most importantly, numerous organisations have not yet resolved ethical considerations about AI implementation. All aforementioned issues demand careful consideration in human-centred designs (Felicetti et al. 2024; Dignum 2022; European Commission 2024). These challenges cast the importance of developing fully articulated frameworks for properly implementing AI, from the sociotechnical to the human to the ethical.

2.4 Gaps in Current Research

The related literature provides a lot of information on applying AI to project management and human-centred design, but many gaps remain. Second, wind farms, solar power plants, and other electric production projects have unique characteristics (Taboada et al. 2023; Olson 2024, 63–79; Kusiak et al. 2010). Little research has been done on these. Second, while most research employs theoretical models or limited situations, none use comprehensive data to determine how human and AI collaboration affects important performance measures (Adamantiadou and Tsironis 2025; Bansal and Nushi 2023). This is especially true for staff satisfaction and adaptability measurements. Human-centric AI project management frameworks are still developing, and few organisation-friendly methods exist (Al-Arafat et al. 2025; Brynjolfsson and Mitchell 2017). To fill these deficiencies, this research creates and evaluates a human-oriented AI framework for electric production project management.

3 METHODOLOGY

3.1 Research Design

The methodology employed in this study consisted of both a qualitative and a quantitative approach, which used data collection and analysis. It was organised as follows:

1. Literature study in depth;
2. Case and analysis development;
3. Interviews and surveys with experts.

3.2 Data Collection

3.2.1 Literature Analysis

An academic article, industry report, and white paper compilation of 87 academic articles published between 2020 and 2025 was conducted. Search terms included combinations of "artificial

intelligence," "project management," "electric production," "renewable energy," "human-centred design," "wind farms," and "solar power plants." The bases for selection were selecting articles relevant to the research questions, rigorous methodological profiles, and citation impact.

3.2.2 Case Studies

Three in-depth case studies were developed focusing on major European energy companies that had implemented AI systems in their wind farm and solar power plant project management over the past three years. Case study data was collected through:

- Document analysis of project reports, implementation plans, and performance metrics
- Site visits to project management offices and operational facilities
- Observations of project management teams using AI systems

3.2.3 Expert Interviews and Surveys

Primary data collection included:

- 24 semi-structured interviews with project managers, AI specialists, and executives from electric production companies
- A survey of 142 project team members across 18 organisations, measuring perceptions of AI tools, collaboration experiences, and satisfaction levels
- Two focus groups with project management professionals to validate preliminary findings

3.3 Data Analysis

Qualitative data from literature, case studies, and interviews were analysed using thematic coding techniques to identify recurring patterns, challenges, and success factors. Quantitative survey data were analysed using descriptive statistics and regression analysis to identify relationships between human-AI collaboration approaches and outcome measures, including efficiency, adaptability, and satisfaction (Adamantiadou and Tsironis 2025). Cross-case analysis was employed to compare implementation approaches and outcomes across the three case study organisations. Triangulation of data sources enabled validation of findings and development of robust insights.

3.4 Ethical Considerations

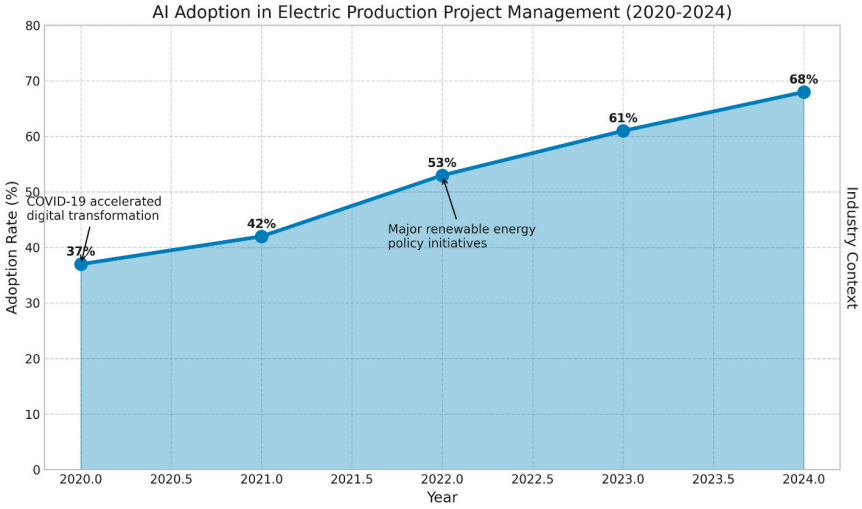
Research ethics approval was obtained prior to data collection. All participants provided informed consent, and organisational data were anonymised to protect confidentiality. The research team maintained independence from the case study organisations to ensure objective analysis.

4 RESULTS

4.1 Current State of AI Implementation in Electric Production Projects

Analysis of industry data reveals that AI implementation in electric production project management has accelerated significantly (Figure 1), with adoption rates increasing from 37% in 2020 to 68% in 2024 (PMI 2023; Chui et al. 2023). However, the depth and sophistication of these implementations vary substantially, with many organisations still in early stages of maturity.

Figure 1: AI Adoption in Electric Production Project Management (2020-2024)



(Source: Author's own elaboration based on PMI 2023 and Chui et al. 2023)

Among the surveyed organisations, four primary categories of AI applications emerged in electric production project management:

1. **Predictive Analytics and Forecasting (86%)**: Using historical data and environmental parameters to predict energy production, timeline variations, and resource requirements
2. **Resource Optimisation (74%)**: Allocating human resources, equipment, and materials across complex project portfolios based on changing priorities and constraints
3. **Risk Assessment and Mitigation (65%)**: Identifying potential risks and recommending mitigation strategies based on project characteristics and historical patterns
4. **Stakeholder Communication and Reporting (47%)**: Automating routine communications, generating customised reports, and analysing stakeholder feedback

These case studies revealed significant variation in implementation approaches. Company A (a large multinational energy corporation) adopted a centralised AI platform integrated with its existing project management systems. Company B (a mid-sized wind farm developer) implemented targeted AI solutions for specific high-value processes. Company C (a solar power specialist) took a hybrid approach, combining in-house AI development with vendor solutions.

4.2 Impact of Human-AI Collaboration on Project Performance

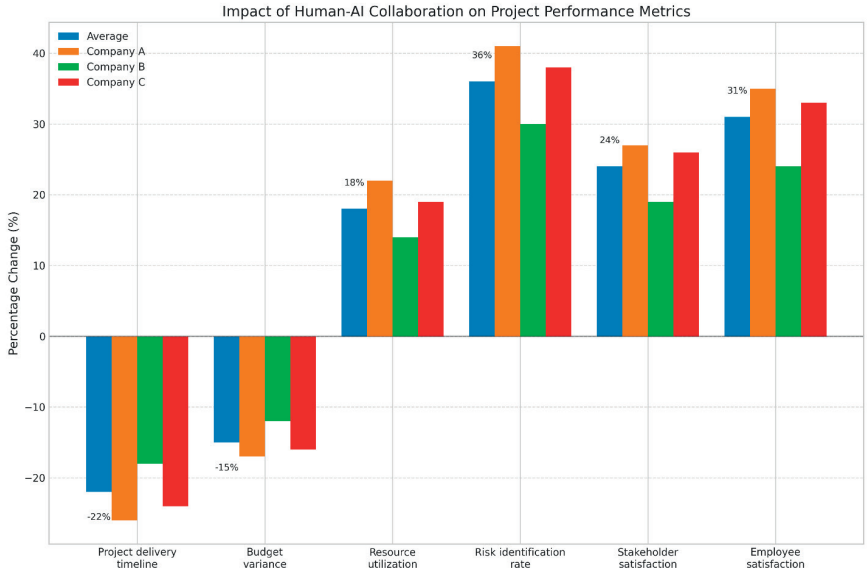
Analysis of performance data from the case study organisations revealed measurable impacts of human-AI collaboration on key metrics (Table 1 and Figure 2). Projects utilising human-centred AI approaches significantly improved compared to historical baseline performance and industry benchmarks (Zhang et al. 2025).

Table 1: Impact of Human-AI Collaboration on Project Performance Metrics

Performance Metric	Average Improvement	Company A	Company B	Company C
Project delivery timeline	-22%	-26%	-18%	-24%
Budget variance	-15%	-17%	-12%	-16%
Resource utilisation	+18%	+22%	+14%	+19%
Risk identification rate	+36%	+41%	+30%	+38%
Stakeholder satisfaction	+24%	+27%	+19%	+26%
Employee satisfaction	+31%	+35%	+24%	+33%

(Source: Author's own work)

Figure 2: Impact of Human-AI Collaboration on Project Performance Metrics



(Source: Author's own work)

Qualitative data provided insight into the mechanisms driving these improvements. Interview participants consistently identified four key factors:

1. Enhanced decision quality: "The AI helps us consider more scenarios and variables than we could manually process, leading to more robust decisions" (Project Director, Company A)
2. Reduced administrative burden: "Automating routine tasks freed our team to focus on strategic activities and stakeholder engagement" (Project Manager, Company B)
3. Improved predictive capability: "We can now anticipate problems weeks before they would become visible in traditional reporting systems" (PMO Head, Company C)
4. More responsive adaptation: "The combination of real-time data and AI analysis allows us to adjust plans much more quickly when conditions change" (Senior Manager, Company A)

However, these benefits were not uniform across all contexts. Projects with higher complexity, geographic distribution, and stakeholder diversity showed greater improvements from human-AI collaboration than simpler, more localized projects.

4.3 Key Elements of Human-Centered AI Frameworks

Through cross-case analysis and thematic coding of interview data, four essential components of effective human-centered AI frameworks for electric production project management emerged:

4.3.1 Collaborative Intelligence Models

Successful implementations established clear delineation of responsibilities between AI systems and human team members, leveraging the complementary strengths of each (O'Neill et al. 2022; Seeber et al. 2020). As one participant explained:

"We spent significant time defining which decisions should be AI-supported versus human-led. Weather-based production forecasting is almost entirely AI-driven, while stakeholder management and community engagement remain human-centered with minimal AI involvement." (Executive, Company B)

This deliberate allocation of responsibilities created what several participants termed "collaborative intelligence" - a model where AI handles data-intensive analysis while humans provide contextual understanding, ethical judgment, and relationship management.

4.3.2 Explainable AI Interfaces

All three case study organizations emphasized the importance of making AI systems understandable to project team members (Vilone and Longo 2021; Arrieta et al. 2020). This included visualization tools, natural language explanations of recommendations, and transparency about data sources and limitations.

"Our early implementation failed because the system was a black box. Project managers wouldn't accept recommendations they couldn't understand. The current version explains its reasoning, shows confidence levels, and identifies the key factors driving each prediction." (AI Specialist, Company C)

This transparency was particularly important for high-stakes decisions involving safety considerations, significant financial implications, or community impact.

4.3.3 Continuous Feedback Mechanisms

Successful frameworks incorporated robust mechanisms for humans to provide feedback on AI recommendations, creating a continuous learning loop (Bansal and Nushi 2023). This included structured evaluation processes, annotation systems for incorrect predictions, and regular review sessions.

"The system improves because we actively teach it. When it makes a recommendation we disagree with, we don't just override it - we explain why, and that feedback trains the model to make better predictions next time." (Project Manager, Company A)

This approach helped address initial skepticism and build trust in the AI systems over time (Hoffman et al. 2021).

4.3.4 Adaptive Governance Structures

The final key element was governance structures that could evolve as both AI capabilities and human skills developed (Lee and Kim 2024; Mökander and Floridi 2023). This included clear policies on decision authority, escalation processes for AI-human disagreements, and regular review of automation boundaries.

"We established a tiered governance approach. For some decisions, the AI can act autonomously. For others, it recommends but requires human approval. And for strategic or ethical decisions, it provides information but humans maintain full control." (Director, Company B)

These governance structures were not static but evolved as teams gained experience with the systems and as AI capabilities matured.

4.4 Implementation Challenges and Strategies

Despite the demonstrated benefits, all case study organisations encountered significant challenges in implementing human-centered AI. Interview and survey data revealed four primary categories of challenges:

4.4.1 Skills and Capability Gaps

Many project team members lacked the data literacy and AI understanding to collaborate effectively with these systems. Survey results showed that 67% of project managers felt insufficient training to fully leverage AI capabilities (Brynjolfsson and Mitchell 2017; World Economic Forum 2023).

Successful organisations addressed this through comprehensive training programs that focused on technical skills and critical thinking about AI outputs. As one participant noted:

"The training that worked best was not about how to use the software, but how to work with it - when to trust it, when to question it, and how to provide feedback that improves it." (Training Lead, Company A)

4.4.2 Trust and Acceptance Barriers

Resistance to AI-supported decision-making was common, particularly among experienced project managers. This manifested in either over-reliance or under-utilisation of AI systems. „We had two opposite problems: junior team members who accepted every AI recommendation without ques-

tion, and senior managers who ignored valuable insights because they did not trust the system." (PMO Director, Company C). Effective strategies to address this included phased implementation approaches, involvement of project teams in system design, and transparent communication about both capabilities and limitations of AI tools (Venkatesh et al. 2024).

4.4.3 Data Quality and Integration Issues

AI systems in electric production project management require integrating diverse data sources, from weather forecasts and equipment sensors to financial systems and stakeholder feedback. All three case study organisations faced data quality, consistency, and integration challenges (Ginzburg-Ganz et al. 2025; Janssen et al. 2020). Successful approaches included dedicated data governance teams, standardised data protocols across projects, and incremental implementation that began with high-quality data domains before expanding to more challenging areas.

4.4.4 Ethical and Regulatory Considerations

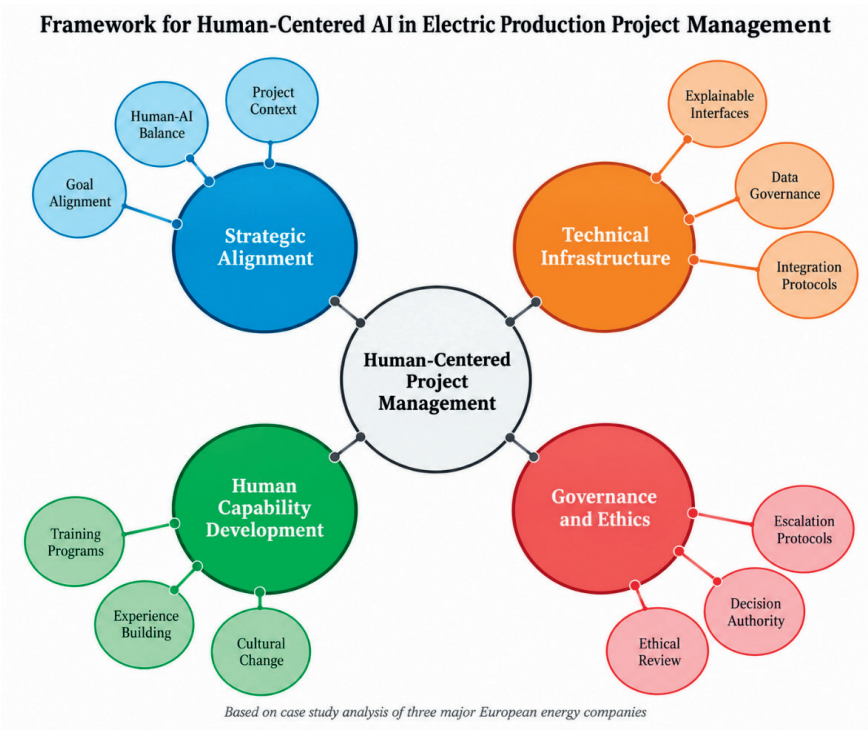
The final category of challenges involved navigating ethical considerations and regulatory requirements (Aizenberg and van den Hoven 2020; ENISA 2023). These included data privacy concerns, algorithmic bias, appropriate levels of automation, and compliance with sector-specific regulations. "We face intense regulatory scrutiny and community engagement requirements in renewable energy projects. We needed to ensure our AI systems helped us meet these obligations rather than creating new risks." (Legal Counsel, Company B). Organisations that successfully navigated these challenges established clear ethical guidelines, involved diverse stakeholders in system design (Park and Lee 2024), and implemented regular ethical reviews of AI applications.

5 DISCUSSION

5.1 Framework for Human-Centred AI in Electric Production Project Management

Based on the research findings, the author of this paper propose an integrated framework (Figure 3) for designing and implementing human-centred AI systems in electric production project management. This framework synthesises the key elements identified in successful implementations while addressing the everyday challenges (Famoti et al. 2025; ENA 2024).

Figure 3: Framework for Human-Centred AI in Electric Production Project Management



(Source: Author's own work)

This framework integrates four enabling components (4c) essential for practical human-centred artificial intelligence (AI) implementation in the electric production project management. Focusing on strategic alignment, strategic alignment is concerned with bringing AI implementation to the same page with the broader organisational objectives, specific project characteristics, and the team's human capabilities and addressing the important job of determining what proportion of the work of any given project should be handled by AI systems and what proportion should be carried out by human experts, given various elements of complexity, risk profiles, and skill base contained within project teams (Brynjolfsson and McAfee 2022; Kaplan and Haenlein 2019).

This alignment further becomes the basis for the technical infrastructure that requires the proper technological foundation for meaningful human-AI collaboration. Through data governance protocols covering all bases (data that is authoritative, complete, accurate, real time, accessible, relevant, available for use when it is needed; interfaces made for explainability so that the reasoning behind the AI is transparent to the users, seamless integration pathways for retaining systems and solutions so that data can be moved within this system, pathways within and outside the system when moving data; feedback mechanisms to allow the AI to keep improving based on human input and the changing conditions) (Opoku et al. 2023).

Regarding the 'people side' of the equation of successful implementation, Human Capability Development acknowledges that it requires training the right skills, developing a deep understanding, and creating the mindsets that facilitate effective collaboration with AI systems (Balakrishnan and Chui 2024). This component consists of structured training initiatives, hands-on opportunities with AI tools, and organisational culture change programs facilitating the organisation's ongoing mindset shift towards collaborative intelligence models.

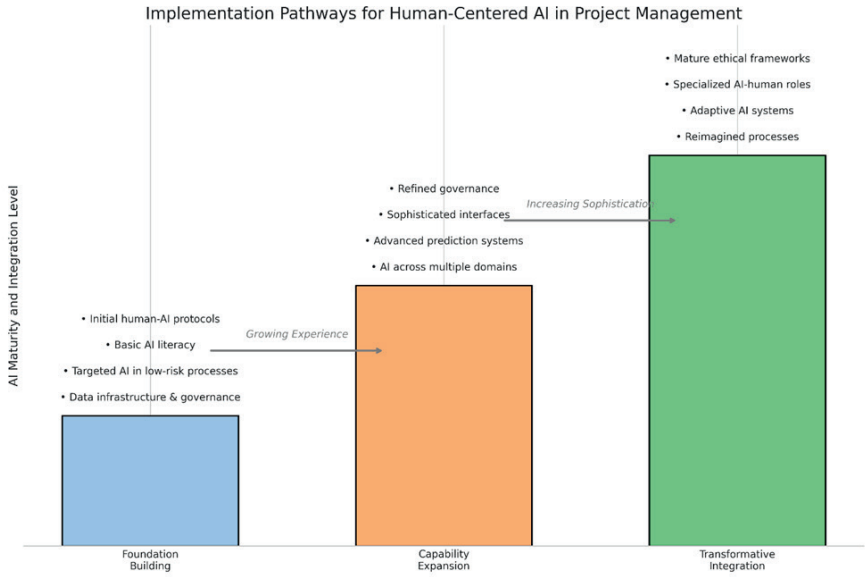
The framework concludes with a Governance and Ethics section, setting the guardrails for responsible AI use (Fjeld et al. 2020; IEEE Standards Association 2024). It involves establishing the rules of decision authority, having a structured process for the escalation when humans and AI systems do not have a common opinion, and a policy mechanism to confirm that ethical considerations

remain at the top of all AI applications in project management contexts. Overall, with the integration of these four components, the framework offers a flexible, comprehensive approach that enables an organisation to customise it to the specific context of the organisation, project portfolio, and AI maturity level, while maintaining at the core of its project management systems human agency and expertise.

5.2 Implementation Pathways

The research further classified three different implementation pathways for the organisation at varying levels of AI maturity (Figure 4). These pathways provide structured approaches for the project management contexts that vary depending on the organisation's readiness and experience with AI technologies.

Figure 4: Implementation Pathways for Human-Centered AI in Project Management



(Source: Author's own work)

5.2.1 Foundation Building

A foundation build approach for non-AI-experienced organisations makes sense. It prioritises this first pathway for establishing the major elements needed for successful AI integration. By now, organisations tend to be working out data infrastructure and governance systems capable of underpinning fast-moving, reliable AI applications. Strategically, they use targeted AI in processes with little risk but still high value, and bring learning without full exposure to failure. There is a parallel effort to build basic AI literacy in the project teams to ensure the staff understands AI capabilities and limitations and has appropriate trust in and usage patterns of AI. Moreover, these organisations created the first human-AI collaboration protocols to explain responsibilities and authorities, among other things. It sets the proper conditions for these more advanced applications, while delivering early wins that create organisational support and momentum for wider AI adoption.

5.2.2 Capability Expansion

With an established foundation of AI, the capability expansion can be pursued to grow and expand human-centred AI implementations. The intermediate path of this pathway involves pulling AI into various project management domains instead of just standalone ones, to create a cohesive ecosystem of AI project management processes. They develop more sophisticated systems in predicting and recommending, responding to multifaceted and difficult-to-solve challenges such as integrated risk assessment and multi-variable resource optimisation. Through advanced human AI interfaces and feedback mechanisms, they build trust through transparency and respond, implement-

ing qualities that improve collaborative quality. They also develop a governance structure based on implementation experience, filling gaps that were identified in the early stage. It follows the initial successes to develop more robust and holistic human-AI collaboration models to create value throughout the project management lifecycle.

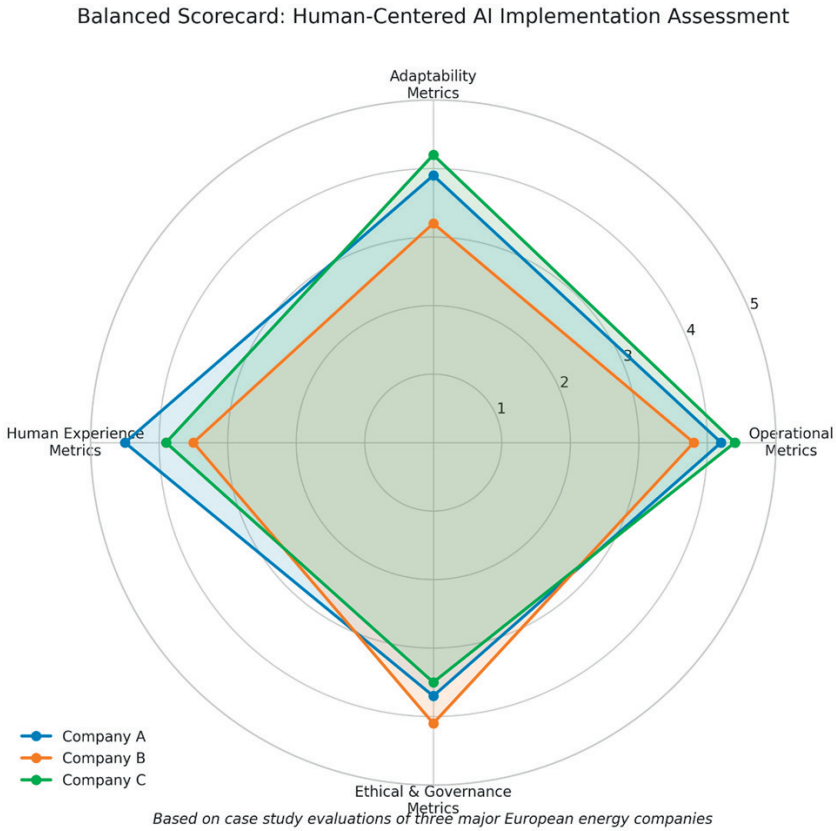
5.2.3 Transformative Integration

The top companies pursue revolutionary integration that overhauls project management. These organisations create human-AI project management workflows and imagine new methods of working that leverage human and AI strengths rather than enhancing old ones. Using highly adaptable AI systems that learn from human feedback and become increasingly valuable partners in difficult decision-making situations. New project management jobs combine traditional project management with AI literacy and facilitation to manage the human-AI ensemble. They create governance frameworks for mature innovation that balance innovation and risk management, responsible experimentation, and security checks. It is the frontier of human-centric AI in project management, enabling new capabilities while focusing on human judgment in essential decision-making.

5.3 Measuring Success

The study recommended multidimensional measures for human-centred AI implementations (Hughes et al. 2025). As AI is integrated into project management, traditional efficiency measurements must complement adaptability, human experience, and ethical considerations (Adamantiadou and Tsironis 2025). The author of this paper suggest a balanced scorecard for four complementary dimensions based on case studies (Figure 5).

Figure 5: Balanced Scorecard: Human-Centered AI Implementation Assessment



(Source: Author's own work)

Instantiation measures provide performance baselines for project delivery time, budget variance, resource utilisation, and quality indicators that reflect tangible business value. Adaptability measures show how quickly an organisation adapts to changes in the situation, how accurate a forecast model is when the environment changes, and how durable the planned scenario is. Human experience metrics measure project team happiness, stakeholder involvement, skill development, and role augmentation after AI adoption (Arshad et al. 2025). Ethics and governance metrics ensure responsible AI use based on decision transparency, bias detection efficacy, adherence to norms and practice guidelines, and stakeholder inclusion in AI-supported decisions. Combining these techniques would help organisations prioritise human considerations and ethics in human-centred AI implementations and efficiency gains for sustainable success.

5.4 Future Research Directions

This research could progress human-centred AI in electric production project management in several interesting directions. The longitudinal investigations would reveal how human-AI collaboration alters as AI capabilities grow and human talents are exercised through persistent interaction. This research could reveal adaptation patterns, learning limits, and factors affecting the sustainability of project-level human-AI relationships. These would also compare human-centred AI applications in power-generating projects to wind, solar, hydro, and other renewables. It could identify industry best practices and basic concepts.

A study on emerging technologies will examine how AI's improved capabilities affect human-centred project management. However, as generative AI, autonomous systems, and multimodal interfaces evolve, their potential to improve or undermine human agency in human-AI interaction must be considered (Adamantiadou and Tsironis 2025). These studies would help explain how AI integration changes skills, jobs, project management competencies, and organisational structures. This research may help improve project management curricula and organisational architecture for AI-using electric production enterprises.

Researching ethical frameworks might help handle the tangled ethical hazards of deploying AI to high-stakes projects. This addresses accountability, openness, justice, and value alignment in decisions with substantial environmental, economic, or social implications. These study directions will help solve the shifting human-centred AI in electric production project management and improve future production efficiency and responsibility.

6 CONCLUSION

Wind farms and solar power plants are examples of complex electric production projects managed by this work's technologies. The paper delivers practical insights for organisations to use AI to maintain human agency in project management based on literature evaluation, case studies, and primary research. These findings show that human-AI collaboration can improve project outcomes regarding delivery time, budget performance, adaptability (risk identification and response to changing conditions), and human experience (team satisfaction and stakeholder engagement). However, technology implementation and human factors must be considered to reap these benefits (Söderholm and Wårell 2024).

This framework covers building human-centred AI systems for electric production project management from strategic alignment to technology infrastructure, people competence, and guidance. Implementation channels provide practical advice for businesses at different AI maturity levels. Human-centred AI techniques are needed to manage project complexity as the electric production sector shifts towards renewable energy and digital technology. Combining AI's analytical strength with human traits like judgement, experience, and ethics helps organisations get AI's full benefits while retaining their human components for project success.

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1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

COMPETENCIES FOR MANAGING SUSTAINABILITY-RELATED TENSIONS IN PROJECTS: A CONCEPTUAL FRAMEWORK

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ABSTRACT

Promoting sustainability is more important than ever. A growing movement is encouraging companies to broaden their responsibilities beyond financial results alone, integrating sustainability performance instead. However, project managers often encounter conflicts and tensions when pursuing sustainability goals. Existing research highlights a significant gap in the critical competencies that project managers require to manage sustainability-related tensions effectively. This study therefore focuses on the competencies that enable project managers to address such issues within projects, thereby improving overall sustainability outcomes. The research question "Which project management competencies have proven relevant for managing sustainability-related tensions in projects?" is addressed through a systematic literature review covering the period from 2014 to 2026. The study produced a competency-based conceptual frame, identifying six key competencies for resolving sustainability-related tensions in projects: These are soft competencies such as communication and stakeholder engagement, systems thinking, reflective action, boundary spanning and pathfinding, as well as the hard skill of sustainability knowledge.

Keywords: *sustainability tensions, competencies, project manager, sustainable project management, project management*

1 INTRODUCTION

1.1 Sustainability-related tensions in projects

Sustainability has become one of the most crucial areas of emphasis in today's business operations (Sabini et al. 2019). Within this paper, sustainability is understood as the balance between three fundamental dimensions: social equity, environmental protection, and economic well-being (Silvius et al. 2012). As there is a growing movement encouraging organisations to broaden their obligations beyond purely financial goals to include sustainability outcomes for all parties involved (Sabini et al. 2019), companies are increasingly embedding sustainability efforts within their overarching corporate vision, mission statements, and strategic plans (Goni et al. 2015). As a result, the idea of 'green' or 'sustainable' project management is widely recognised as a prominent global development in modern project management methodologies (Alvarez-Dionisi et al. 2016). The challenges project managers face when addressing sustainability objectives reveal that tensions connected to sustainable goals, such as the scheduling of targets, organizational barriers, and restricted authority, are only effectively handled when justified by an economic rationale (Sabini and Alderman 2021). Moreover, since it is unfeasible to fully reconcile traditional project aims with sustainability ambitions, practitioners often react with behaviours characterised as greenwashing. These include attitudes such as it can't be one person's responsibility or there is no room for sustainability in my role, the involvement of additional stakeholders, or outright resistance, depending on the specific context of the project (Sabini and Alderman 2021). Project managers encounter behavioural challenges that hinder the integration of sustainability practices within their projects (Friedrich and Wehnert 2025). When undertaking a project, it is exceedingly difficult to establish a set of objectives that comprehensively fulfil the broad concept of sustainability, which includes environmental, social, and economic dimensions simultaneously (Sabini and Alderman 2021). Within this framework, sustainability demands that managers tackle multiple beneficial yet frequently conflicting economic, environmental, and social aims concurrently at both the organisational and societal levels. These goals unfold over different time horizons and are governed by distinct underlying principles (Hahn et al. 2014), a challenge particularly pertinent to project managers. A limited overall comprehension and awareness of sustainability among the diverse members of a project team, which cannot be solely attributed to the project manager, results in project managers experiencing a sense of diminished control (Sabini and Alderman 2021). For this reason, it is essential for professionals to acquire a thorough understanding of sustainability. Modern project settings are progressively characterized by contradictory tensions, such as the balance between control and adaptability, immediate results and sustained value, or productivity and creativity that demand project practitioners to develop a more sophisticated range of competencies (Cantoni et al. 2026). Viewed through the lens of paradox theory, these conflicting demands are not settled by making final decisions (trade-offs) but must be managed on an ongoing basis. Consequently, project managers need to foster dynamic and self-aware interpersonal competencies that allow them to interact effectively with these persistent contradictions (Schad et al. 2016; Farjoun 2010; Miron-Spektor et al. 2018). In order to understand which competencies are effective, it is first necessary to characterise the tensions they are intended to address. The most frequently cited tension is the temporal misalignment between the inherently bounded timelines of projects and the open-ended, intergenerational nature of sustainability objectives (Sabini and Alderman 2021; Cantoni et al. 2026; Sabini et al. 2019). Sabini and Alderman (2021) found that, when this tension arises, sustainability objectives are only addressed when they are anchored to an economic business case. Sarkheyli et al. (2025) documented specific examples in the Oceanhamnen case study, such as the termination of an ecological infrastructure project due to financial constraints and the preference for high-value real estate over affordable housing. Multiple sources also emphasise that sustainability goals are difficult to standardise, which makes things more challenging for project managers who are used to conventional control mechanisms (Ambituuni et al. 2025; Ziafati Bafarasat 2026).

1.2 Competencies

Competencies are defined as a combination of interrelated components involving knowledge, skills, and attitudes (Lizzio and Wilson 2004; Banathy 1987). **Hard competencies** pertain to technical expertise and can be measured objectively using standardized evaluation tools (Cantoni et al. 2026). Hard skills refer to the abilities that enable people to carry out specific tasks effectively. They encompass expertise in scientific understanding, vocational competencies and technical proficien-

cies (Laker and Powell 2011). Hard skills pertain to instructible capabilities connected to technical tasks (Patacsil and Tablatin 2017). In contrast to hard competencies, **soft competencies** involve both intrapersonal and interpersonal capabilities (Cantoni et al. 2026). Soft competencies encompass the abilities that allow employees to integrate effectively within a work environment. These include attributes connected to an individual's personality, character traits, adaptability, drive, objectives, and personal preferences (Laker and Powell 2011). Soft skills cover emotional competencies and behavioral traits necessary for effective teamwork (Patacsil and Tablatin 2017). The aim of the paper is to examine the competencies that help project managers address sustainability-related tensions in their projects.

1.3 Paradox theory

Paradox theory has emerged as a meta-framework designed to address the ongoing tensions within complex and dynamic systems (Sparr et al. 2022). Paradoxical tensions require a comprehensive, evolving strategy, since a unilateral or conciliatory reaction tends to be temporary, with the tension re-emerging and potentially escalating as time progresses (Lewis and Smith 2014). Sustainability involves achieving both short-term and long-term goals without compromising the ability to achieve them in the future (Smith et al. 2011). A paradoxical perspective involves engaging with competing forces simultaneously and continuously. It asks, "How can we support both A and B at the same time?" (Lewis and Smith 2014). Hahn et al. (2018, 237) describe the paradox perspective regarding an organization's sustainability challenges in this way: "A paradox perspective on corporate sustainability embraces interconnected but contradictory economic, environmental, and social issues in order to deliver enhanced business contributions to sustainable development." The paradox theory functions as a conceptual framework to identify the competencies that support project managers to solve sustainability-related tensions in projects.

2 PURPOSE AND GOALS

Integrating sustainability elements into projects generates tensions, reflecting differing timelines linked to sustainable objectives as well as challenges within the organisational or project context. Project managers often experience a feeling of limited influence, attributed to deficiencies in technical knowledge and institutional backing, which is understandable given their intermediate position. These conflicts lead professionals to adopt defensive strategies (Sabini and Alderman 2021; Silvius and Huemann 2024). Future studies should focus on investigating how project managers perceive Sustainable Project Management and the approaches they use to navigate the uncertainties and pressures stemming from sustainability requirements. This is particularly pertinent when such demands are contrasted with traditional project performance goals and evaluation standards (Sabini et al. 2019), as well as identifying the additional competencies project managers must develop to effectively implement sustainable project management practices (Silvius and Schipper 2014). Current research highlights a significant gap concerning the competencies necessary for project managers to address sustainability-related tensions in projects, as it remains unclear which competencies are essential for managing these tensions. Consequently, this systematic literature review concentrates on the micro level. The aim is to pinpoint particular competencies of project managers that have already demonstrated their importance in managing tensions associated with sustainability. This paper answers the following research question: Which competencies have proven to be relevant in managing sustainability-related tensions? The objective is to develop a competency-based conceptual model that pinpoints the competencies enabling project managers to navigate sustainability-related tensions in projects, thus establishing the basis for later empirical verification.

3 METHODOLOGY

An inductive qualitative methodology (Maylor et al. 2017) was employed for the literature review to identify the competencies that project managers utilise when dealing with sustainability tensions. Relevant passages from the sources were extracted and categorised inductively into two main groups, soft competencies and hard competencies. The subcodes were coded inductively when coding the hard and soft competencies. In a subsequent analysis phase, the excerpts were organised

and coded using MAXQDA (Version 26.0.0) to identify recurring themes and thematic groupings. These codes were then grouped into thematic categories, which are detailed in **Table 1**.

Table 1: Codes and subcodes

1st order code	Subcode
Soft competencies	Agenda setting
	Active empathy
	Ethical commitment
	Pathfinding
	Boundary spanning
	Reflective action
	Communication and stakeholder engagement
	Systems thinking
	Project monitoring
Hard competencies	Technical competencies
	Sustainability competencies

(Source: Author's own work)

A literature search was conducted to examine the competencies that help project managers manage sustainability-related tensions. Due to availability the search was carried out methodically using Scopus. This database was chosen because it predominantly indexes peer-reviewed academic articles and provides standardized tools that enable precise and verifiable search queries, thus ensuring the high caliber of the literature included. Also Scopus has superior coverage of management literature to Web of Science and indexes more relevant journals. Additionally, the top four project management journals (IJPM, PMJ, IJMPB, PLAS) were scanned separately for the reason not to miss a relevant article. Google Scholar was deliberately omitted from the systematic search due to its technical constraints, notably the challenges in consistently tracking and exporting data for thorough analysis, as well as the absence of standardized, reproducible filtering options. By concentrating exclusively on Scopus and reviewing the four principal project management journals, the approach guarantees that only indexed, peer-reviewed sources are considered, thereby enhancing the reliability of the data synthesis. The timeframe for the search was precisely limited to include only publications dated from January 2014 through to February 2026. The search string was designed to capture the intersection of the key concepts: "(Competenc* or skill or abilit*) AND sustainabilit* AND (Paradox OR tension OR conflict OR barrier OR problem solving) AND project".

This search strategy required publications to cover the conceptual areas at the intersection of our core theoretical domains. However, this restrictive approach may have excluded relevant articles dealing with project manager competencies in general that did not explicitly mention tensions or sustainability. The narrow scope of the review was deliberately chosen to ensure theoretical consistency. A further selection was made based on accessibility via institutional subscriptions and open access availability, as well as the introduction and conclusion (Armbruster and Huemann 2025).

The final inclusion criteria required that the publications: (1) focus on project managers as an individual, (2) examine project manager competencies, (3) address tensions, paradoxes, challenges, barriers, problem-solving or conflicts related to sustainability, (4) are papers from quartile 1+2 journals (Q1 and Q2) according to Scimago, (5) must be peer-reviewed articles, (6) publications must be available in English and (7) published in the timeframe 01/2014 – 02/2026. Publications were excluded if they focused exclusively on the general competencies of project managers, if the tensions were not related to sustainability, or if the competencies were only mentioned marginally and were not the main focus or the journals are not in Q1 or Q2 according to Scimago or are not peer-reviewed journal articles. To increase the number of results, the search string has been expanded from ‚(Competenc* or skill or abilit*) AND sustainabilit* AND (Paradox OR tension) AND project manager' to ‚(Competenc* or skill or abilit*) AND sustainabilit* AND (Paradox OR tension OR conflict OR barrier

OR problem solving) AND project'. As a result, 9 articles were selected for the systematic literature review. Fewer journal articles could be included than originally planned due to the available data and the exclusion criteria. **Table 2** shows the numbers of records identified by databases. The articles examined were published between 01/2014 and 02/2026, and were sourced from a variety of scientific journals. At the outset, the articles in the structured literature review were read thoroughly in order to understand their main ideas, background and conceptual framework on the topic of project managers' competencies in overcoming sustainability-related tensions. A list of coded excerpts was then created to facilitate the final analysis of the results. The codes were manually assigned in MAXQDA. **APPENDIX I** gives an overview of the nine examined sources.

Table 2: Numbers of articles found

Database	Search string	Document type and language	Selection based on Abstract and keywords	Selection based on detailed reading	Included papers in the SLR
Scopus	n = 95			n = 87	n = 6
PLAS	n = 84			n = 84	n = 0
IJPM	n = 40			n = 39	n = 1
PMJ	n = 195			n = 194	n = 1
IJMPB	n = 308			n = 307	n = 1
All	n = 722			n = 712	**n = 9**

(Source: Author's own work)

4 RESULTS

The nine studies reveal a consistent pattern: relational and interpersonal competencies are more effective in resolving sustainability tensions than technical or analytical ones. **Figure 1** shows the most important competencies ranked from most to least important.

Figure 1: Sample scope distribution and number of cases of subcodes

(Source: Author's own work)

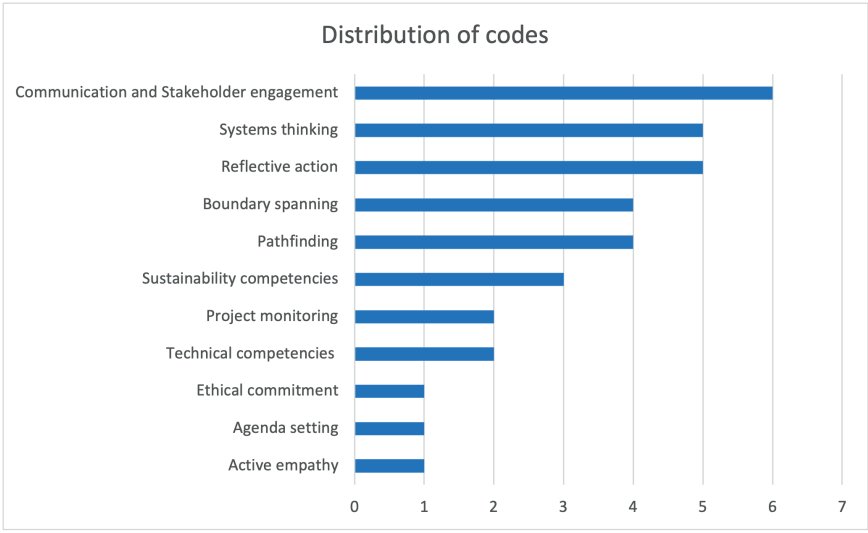


Table 3 maps the competencies identified across sources and indicates which tensions each competency is positioned to address.

Table 3: Competencies addressing sustainability-related tensions in projects

Competencies	Description	Tension type addressed	Tension description	Sources tensions
Reflective action	Designing and driving small fixes to urgent sustainability problems and reflecting on outcomes (Ziafati Bafarasat 2026); Ability to make informed decisions under sustainability constraints (Toljaga-Nikolić et al. 2020)	**Short-term vs. long-term objectives**	Conflict between immediate project deliverables and long-term sustainability goals; Complexity; economic vs. environmental goals; social equity tension;	Short-term operational exigencies vs. long-term socio-environmental imperatives (Cantoni et al. 2026); different time horizons for PM vs. sustainability (Sabini et al. 2019); Temporality of objectives is a primary tension (Sabini et al. 2019)
Ethical commitment and social responsibility	Respect for diversity, intercultural understanding, ethical commitment (Cantoni et al. 2026);			
Pathfinding	Providing anticipatory solutions for evolving sustainability problems (Ziafati Bafarasat 2026)			
Knowledge about sustainability	Comprehensive knowledge on sustainability and awareness of sustainability dimensions and "green" technologies and materials			
Communication and stakeholder engagement;	Dialogue with internal and external stakeholders; feedback collection (Sarkheyli et al. 2025); communication as the top-ranked skill for sustainable PM (Toljaga-Nikolić et al. 2020);	**Organizational barriers; stakeholder complexity**	Difficulty demonstrating sustainability benefits; fear of job loss; lack of senior management commitment	Regulatory, educational, and cultural barriers (Abou-Warda 2014); resistance to new methods (Todorova et al. 2025) organizational-goal misalignment (Ambituuni et al. 2025)
Boundary spanning	Crossing technical, cultural, disciplinary, and professional boundaries to cooperate (Ziafati Bafarasat 2026)			
Agenda-setting	Guiding engagement and ensuring compliance with sustainability requirements (Sarkheyli et al. 2025)			
Project monitoring	Flexible, context-sensitive execution control including stakeholder collaboration and real-time correction (Ambituuni et al. 2025)			
(Intrinsic motivation)				
Technical competencies	Strategic planning, financial analysis, risk assessment, sustainability accounting; Less effective than continuous competencies in regression analysis (Abou-Warda 2014)	**Economic vs. environmental/ social goals; process vs. outcome sustainability**	Sustainability pursued only when anchored to an economic business case; Rigidity vs. flexibility; sustainability goal ambiguity	Economic imperatives often drive sustainability integration (Sabini et al. 2019); cost-effectiveness vs. ecological sustainability in urban planning (Ambituuni et al. 2025); financial constraints and cost vs. environmental impact (Todorova et al. 2025)
Project monitoring	Flexible, context-sensitive execution control including stakeholder collaboration and real-time correction (Ambituuni et al. 2025)			
Communication, stakeholder engagement,	Dialogue with internal and external stakeholders; feedback collection (Sarkheyli et al. 2025); communication as the top-ranked skill for sustainable PM (Toljaga-Nikolić et al. 2020)	**Lack of control and knowledge**	Insufficient knowledge of sustainable best practices and institutional support	Public sector knowledge gaps about sustainability dimensions (Toljaga-Nikolić et al. 2020); lack of shared understanding of sustainability concepts (Sarkheyli et al. 2025); sustainability goals resist standardization (Ambituuni et al. 2025)
Agenda-setting	Guiding engagement and ensuring compliance with sustainability requirements (Sarkheyli et al. 2025)			
Sustainability competencies	Comprehensive knowledge on sustainability and awareness of sustainability dimensions and "green" technologies and materials that enable to sustainable project management and execution (Toljaga-Nikolić et al. 2020);			
(Intrinsic motivation)				

Systems thinking; **Reflective action** **Pathfinding**	Accounting for known, unknown, and unknowable relationships in a problem context (Ziafati Bafarasat 2026); understanding complex interdependencies (Sabini et al. 2019); Designing and driving small fixes to urgent sustainability problems and reflecting on outcomes (Ziafati Bafarasat 2026); Ability to make informed decisions under sustainability constraints (Toljaga-Nikolić et al. 2020) Providing anticipatory solutions for evolving sustainability problems (Ziafati Bafarasat 2026)	**Complexity and wickedness**	Sustainability problems are complex and chaotic with interdependent, contradictory requirements	Sustainability conflicts as wicked problems (Sarkheyli et al. 2025); complexity and ambiguity vs. traditional project control (Ambituuni et al. 2025)
Active empathy	Standing for sufferers of sustainability problems (Ziafati Bafarasat 2026)	**Social equity vs. economic development**	Tension between affordable housing and high-value real estate; sustainable mobility vs. parking demands	Comprehensive stakeholder demands due to sustainability integration (Toljaga-Nikolić et al. 2020); Lack of affordable housing vs. economic objectives (Sarkheyli et al. 2025)
Systems thinking	Accounting for known, unknown, and unknowable relationships in a problem context (Ziafati Bafarasat 2026); understanding complex interdependencies (Sabini et al. 2019) Comprehensive knowledge on sustainability	**Process sustainability vs. outcome sustainability**	Tension between doing projects sustainably and delivering sustainable outputs	Rigidity of control frameworks vs. need for flexibility (Ambituuni et al. 2025); SPM might do the "wrong things, albeit in the right way" (Sabini et al. 2019)
Intrinsic motivation	Personal principles driving sustainability efforts (Sabini and Alderman 2021); usually not seen as a competency	**All tensions**; especially organizational barriers and lack of control (Sabini and Alderman 2021)	See descriptions above	See descriptions above

(Source: Author's own work)

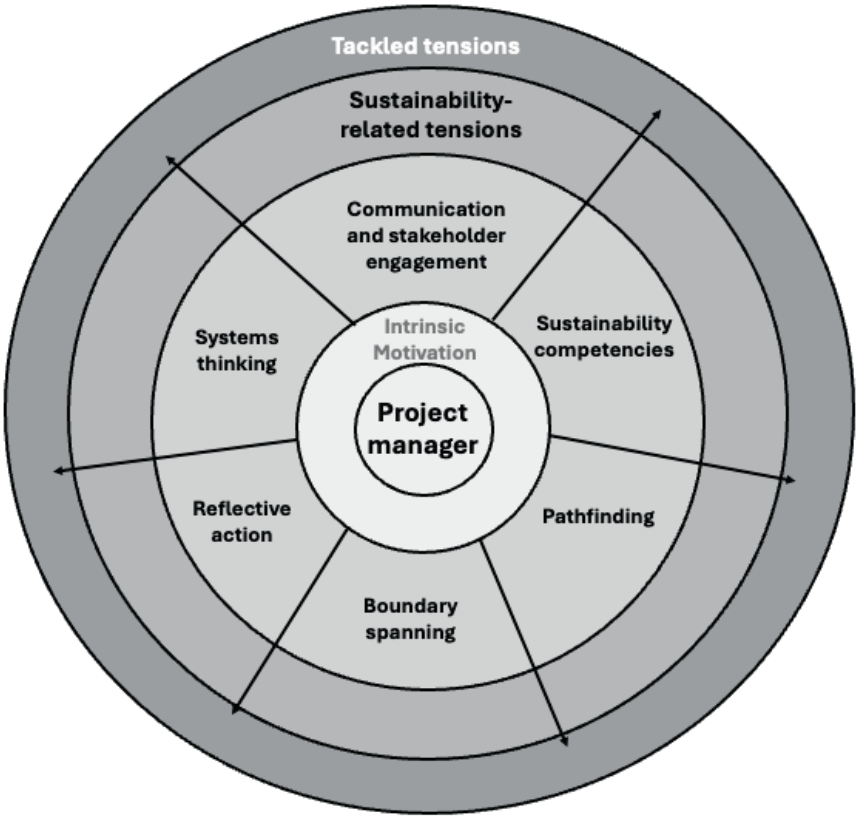
The tensions converge around a central paradox: project management's traditional orientation toward bounded, time-limited deliverables clashes with sustainability's open-ended, systemic, and long-term nature (Sabini and Alderman 2021; Sabini et al. 2019). This paradox is compounded by organizational cultures that reward short-term operational outcomes over sustainability-related achievements (Cantoni et al. 2026). Communication and stakeholder engagement emerge as the most consistently prioritized competency (Toljaga-Nikolić et al. 2020; Abou-Warda 2014; Ambituuni et al. 2025). Sustainability-related ethical competencies are deemed essential but are systematically undervalued (Cantoni et al. 2026). Intrinsic motivation is the most effective attitudinal driver. Sabini and Alderman (2021) found that project managers driven by personal sustainability principles (intrinsic motivation) were more effective in addressing sustainability tensions than those driven by compliance (task-driven behavior) or pragmatism (acting only when practical applications are evident) (Sabini and Alderman 2021). When intrinsic motivation was absent, sustainability objectives were pursued only when anchored to an economic business case, and practitioners enacted a set of avoidance reactions including greenwashing, deflection of responsibility, and "pushing back" (Sabini and Alderman 2021).

5 DISCUSSION

A clear pattern emerges from the nine studies: relational and interpersonal competencies are more effective in resolving sustainability tensions than technical or analytical competencies alone. Abou-Warda (2014) demonstrate quantitatively that interpersonal competencies have a greater impact on sustainability outcomes than technical competencies. Toljaga-Nikolić et al. (2020) corroborate this finding, emphasising the importance of communication. Cantoni et al. (2026) identify a discrepancy: sustainability-specific competencies, such as ethical commitment, are undervalued by practitioners compared to operational skills, such as reflective action and boundary spanning. This indicates a discrepancy between the competencies required and those rewarded in project man-

agement. Sabini and Alderman (2021) identify intrinsic motivation as the most critical driver of effective sustainability engagement, playing a foundational role. Without it, project managers may exhibit defensive behaviours such as greenwashing or shirking responsibility. Therefore, intrinsic motivation is less a competency and more an orientation that enables the application of other competencies to address sustainability issues. While the studies agree on the importance of interpersonal competencies and knowledge of sustainability, they diverge on their perceived importance and adoption. Studies focusing on effectiveness find interpersonal skills and knowledge about sustainability to be crucial, whereas studies on practitioner priorities show that, despite their long-term importance, sustainability competencies like ethical commitment or social responsibility are ranked low. This discrepancy may account for the uneven integration of sustainability, as prevailing evaluation systems favour short-term operational metrics. Furthermore, Sabini and Alderman (2021) note that practitioners avoid engagement when sustainability cannot be linked to economic returns, indicating that organisational incentives and institutional support strongly influence competency application. Context also plays a role. For example, Toljaga-Nikolić et al. (2020) highlight a lack of sustainability knowledge in the public sector. Ambituuni et al. (2025) demonstrate that, as uncertainty increases, adaptive, flexible governance approaches outperform hierarchical ones. Ziafati Bafarasat (2026) argues that, due to their complexity, sustainability-related tensions require spontaneous responses. In urban planning, Sarkheyli et al. (2025) demonstrate that the effectiveness of policies depends on inclusive implementation, noting that dialogue fails when marginalised stakeholders are excluded. Overall, the following conceptual model is emerging: intrinsic motivation forms the foundation for a genuine commitment to sustainability. As shown in **Figure 2**, soft competencies, such as communication and stakeholder management, systems thinking, reflective action, boundary spanning, pathfinding as well as the hard competency of sustainability knowledge, support project managers in tackling sustainability-related tensions in projects. However, organisational frameworks that undervalue sustainability competencies and fail to provide the necessary training, incentives and knowledge infrastructure present an obstacle. Studies focusing on organizational and institutional barriers consistently point to interpersonal and relational competencies like communication and stakeholder engagement, reflective action and pathfinding as most effective (Toljaga-Nikolić et al. 2020; Abou-Warda 2014; Ambituuni et al. 2025). In contrast, studies examining the deeper paradoxes of sustainability (short-term vs. long-term, process vs. outcome) emphasize higher-order cognitive and attitudinal competencies such as systems thinking (Ziafati Bafarasat 2026; Sabini et al. 2019), intrinsic motivation (Sabini and Alderman 2021), and ethical commitment (Cantoni et al. 2026). This is not a contradiction but rather a reflection that different competencies operate at different levels: interpersonal competencies manage the day-to-day friction of sustainability implementation, while cognitive-attitudinal competencies shape whether sustainability is meaningfully pursued at all.

Figure 2: Model of proven competencies to tackle sustainability-related tensions in projects



(Source: Author's own work)

6 CONCLUSION

In theory, this paper introduces an innovative framework that defines competencies as the abilities enabling project managers to navigate sustainability-related tensions and contradictions, handle complexity, and develop solutions, without making concessions. In practice, it calls for competency models, academic programmes and professional development structures to be revised to encourage a more timely and ethically informed understanding of competencies to help project managers address sustainability-related tensions. Different competencies operate at different levels. Interpersonal competencies like communication and stakeholder engagement manage the day-to-day challenges of implementing sustainability, while cognitive-attitudinal competencies as systems thinking determine whether sustainability is pursued meaningfully at all. The limitations of this study stemmed from the small number of studies that could be included in the review. This limitation will be overcome in the next step of the PhD research process. Several expert interviews are planned. These will be used to secure the findings. Further studies on project manager competencies are therefore recommended to determine which are essential for resolving sustainability-related tensions in projects. In particular, the effectiveness of these competencies should be investigated.

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APPENDIX I

Study title	Authors	Study type	Research approach
Education for Problems of Sustainable Development	Ziafati Bafarasat 2026	Literature review	Qualitative; deductive and Inductive analysis of 99 records
Project control practices to enable sustainable project management	Ambituuni et al. 2025	Empirical study	Mixed methods; hesitant-fuzzy Delphi and interpretive structural modelling; 13 experts (Delphi) and 11 experts (ISM) with SPM experience
25 years of 'sustainable projects'. What we know and what the literature says	Sabini and Alderman 2021	Literature review	Qualitative; thematic and descriptive analysis of 770 publications (1993–2017)
The Paradoxical Profession: Project Management and the Contradictory Nature of Sustainable Project Objectives	Sabini and Alderman 2021	Empirical study	Qualitative; grounded-style analysis of 14 semi-structured interviews
Understanding Sustainability Competences Through a Paradox Lens: Evidence From Project Management Practice	Cantoni et al. 2026	Empirical study	Mixed methods; survey (n=149) and executive focus groups
Developing Sustainability Problem-Solving Skills Through Internet of Things Projects	Todorova et al. 2025	Empirical study	Mixed methods; SLR and case study analysis
Managing sustainability conflicts in urban development projects: Planners' perceptions and strategies in Oceanhamnen, Helsingborg	Sarkheyli et al. 2025	Empirical study	Qualitative case study; Qualitative; Thematic analysis of 11 interviews; 11 planners and key actors in urban development
Mediation effect of sustainability competencies on the relation between barriers and project sustainability (the case of Egyptian higher education enhancement projects)	Abou-Warda 2014	Empirical study	Quantitative; mediation model with correlations and multiple regression; 159 respondents (project managers, executive teams, experts)
Project Management and Sustainability: Playing Trick or Treat with the Planet	Toljaga-Nikolić et al. 2020	Empirical study	Quantitative; survey with Nonparametric tests; 103 respondents from public and private sectors

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1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

THE DYNAMIC INTERPLAY BETWEEN ORGANIZATIONAL AMBIDEXTERITY AND PROJECT AMBIDEXTERITY: A COMPREHENSIVE REVIEW

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ABSTRACT

The concept of organizational ambidexterity requires organizations to conduct both their exploratory and their exploitative activities at the same time, whereas project ambidexterity aims to handle these opposing requirements which arise in project and portfolio management. Organizations have examined ambidextrous capabilities as strategic resources yet researchers have failed to provide a complete understanding of how organizations and projects implement sustain and develop ambidexterity during digital transformation processes. The current research study conducts an extensive literature examination which merges previous studies about organizational and project ambidexterity with their effects on three areas of innovation and operational efficiency and organizational adaptability and healthcare and manufacturing industry applications. The review uses ambidexterity theory and dynamic capabilities together with knowledge-based perspectives to examine research findings from both empirical studies and theoretical papers to discover essential elements that enable organizations to achieve ambidextrous operations. The analysis demonstrates that digital transformation functions as a fundamental element which establishes itself as both an initiator and controller of ambidexterity by affecting knowledge distribution and executive behavior and project management and innovation development. Effective ambidexterity requires multiple levels of integration which include leadership alignment and cross-functional team structures and project portfolio management methods. The research findings demonstrate that organizations need cross-level operational systems which include multiple organization levels to achieve effective results. The review combines separate research studies to build theoretical knowledge while offering practical guidance to managers and policymakers who want to implement ambidexterity across their organizations and projects in rapidly changing technology environments.

Keywords: *organizational ambidexterity, project ambidexterity, digital transformation, innovation management*

1 INTRODUCTION

Investigation into the connection between organizational ambidexterity and project ambidexterity is important to the study area since it enables firms to improve innovative and adaptive abilities that will help them handle difficult circumstances (Zhang et al. 2021; Durugbo 2023). Ambidexterity is defined as a firm's involvement in both exploratory and developmental activities. Its definition has expanded from organizational studies to its implementation in projects and digital transformation projects (Liu et al. 2012; Hoessler and Carbon 2023). Currently, organizations need to develop innovative capabilities of revolutionary and incremental innovation to ensure that they continue innovating technologically ahead of their competitors, who deal in manufacturing and healthcare sectors (Park and Nahm 2023; Ma et al. 2022). Research indicates that ambidextrous organizations perform well and are flexible at the same time as digital transformation technology helps them to achieve the latter. Organizational ambidextrous innovation capability helps firms to have improved performance while carrying out their businesses even during periods of market disruption (Kafetzopoulos et al. 2023; Xiaokai Li et al. 2024).

Research on organizational ambidexterity has provided partial insight into how organizations utilize and manage their ambidexterity in project management especially their ambidexterity management in project teams and project portfolios (Petro et al. 2020; Lei et al. 2023; Ojiako et al. 2021). There is a view that cross-functional teams along with leadership collaborate to achieve organizational ambidexterity (Zhang et al. 2021; Zheng et al. 2023), while there is another view that organizational contradictions become barriers to innovation success (Glatin et al. 2018; Zheng et al. 2023). The relationship between digital transformation and ambidexterity remains unclear due to disagreement among experts on the impact of this issue on the effectiveness of exploration and exploitation (Xingong Li et al. 2024; Hoessler and Carbon 2023). It is difficult for organizations to address these issues because organizations that do not apply appropriate ambidexterity management techniques will fall into innovation traps and inefficiencies (Durugbo 2023; Park and Nahm 2023). Scholars have to understand all mechanisms and contextual factors driving organizations to develop ambidexterity on various organizational levels (Lastra and Sánchez-Gardey 2024; Killen et al. 2023).

Ambidexterity in the organizational context refers to the capacity of the organization to engage in exploratory and exploitation business processes simultaneously. While the former refers to the general capacity of the organization to perform exploratory and exploitation business processes, the latter refers to the ability of the organization to manage these processes in particular project environments (Durugbo 2023; Sailer 2019). Digital transformation brings about new business contexts which facilitate knowledge sharing and technology integration for achieving ambidextrous innovations according to (Jiang et al. 2024); and (Zhu and Li 2023). The two concepts form a theoretical framework which integrates ambidexterity theory with dynamic capabilities and knowledge perspectives for understanding innovative success of organizations (Lieshout et al. 2021; Cheah and Tan 2023).

The review is designed to bring together the existing research which looks into how organizations and projects perform their dual business operations using their innovative and efficient capability and ability to remain flexible through digital transformations in both healthcare and manufacturing industry sectors. This systematic review will fill the existing research gap by integrating the theoretical and empirical aspects of ambidexterity in organizations and creating research pathways for future research works (Durugbo 2023; Sartori and Garrido 2023).

The study uses the method of systematic literature review, where some inclusion criteria are used to explore the concepts of ambidexterity, innovation, and digital transformation in organizations and projects. Ambidexterity and dynamic capabilities theory are used as the theoretical frameworks for exploring the research findings on ambidexterity in different contexts.

2 PURPOSE AND SCOPE OF THE REVIEW

2.1 Statement of Purpose

This report aims to review the current literature on "Dynamic interplay between organizational ambidexterity and project ambidexterity, specifically innovation, efficiency, adaptability, theoretical

frameworks, practical implications, technology, healthcare, manufacturing". The review is important because organizational ambidexterity and project ambidexterity are what make up the crucial capability which makes it possible for companies to explore new opportunities and pursue innovations as well as keep running their businesses. This review includes a review of theoretical background and empirical evidence and practical implementations and gives an overall picture that will be helpful for organizations in ambidexterity management.

The present study will investigate the impact of digital transformation and technological advancement on organizations adopting dual innovation strategies while maintaining operational efficiency. The results of the study will be important for future research and management practices in organizations.

2.2 Specific Objectives

The study aims to investigate existing knowledge about how organizations achieve ambidexterity through their operational practices and their effectiveness in driving innovation and adaptive capabilities throughout their activities. The researchers will analyze current theoretical models that describe how organizations in healthcare and manufacturing industries maintain their operational balance between new exploration and existing resource exploitation. The research study will identify and combine practical results from ambidexterity studies that organizations can use to increase their operational performance and research development success. The study investigates how digital transformation and technology integration work together to create organizational and project-based ambidextrous capabilities. The research study aims to investigate how team diversity and leadership interact with management methods to create an environment which supports innovative development across projects.

3 METHODOLOGY OF LITERATURE SELECTION

3.1 Transformation of Query

The initial research topic – the dynamic interplay between organizational and project ambidexterity, with particular focus on innovation, efficiency, adaptability, theoretical frameworks, practical implications, technology, healthcare, and manufacturing – served as the basis for developing multiple specific search statements. This broad topic was then divided into several focused research inquiries, ensuring that the literature search achieved complete coverage of all relevant studies while maintaining a controlled and systematic search process.

3.2 Screening Papers

The Inclusion and Exclusion Criteria enables us to execute your modified search requests which produce specific research documents from our database that contains more than 270 million research papers. During this process we found 443 papers.

Citation Chaining - Identifying additional relevant works

- Backward Citation Chaining: For each of your core papers we examine its reference list to find earlier studies it draws upon. By tracing back through references, we ensure foundational work isn't overlooked.
- Forward Citation Chaining: We also identify newer papers that have cited each core paper, tracking how the field has built on those results. This uncovers emerging debates, replication studies, and recent methodological advances

The process results in the discovery of 41 new research papers to study.

4 RESULTS

4.1 Thematic Review of Literature

The research about ambidexterity in organizations and projects shows that organizations need to balance exploration with exploitation because this balance drives their abilities to innovate and operate efficiently and adapt to change in multiple fields such as healthcare and manufacturing.

Digital transformation acts as a primary driver that enables organizations to achieve their dual innovation goals while improving their operational results through knowledge sharing and technology deployment and their strategic management practices. Theoretical frameworks cover all three types of ambidexterity which organizations can use to achieve their goals through leadership development and building diverse teams and implementing specific project management techniques. New research topics investigate how decision-making processes interact with dynamic capabilities and environmental factors yet organizations face new challenges which make it difficult to maintain their dual innovation practices during times of technological and operational change.

Table 1: Themes extracted from literature

Theme	Theme Description
Digital Transformation and Ambidexterity	Digital transformation enables organizations to achieve ambidexterity at both organizational and project levels because it uses technology with digital collaboration tools to create new knowledge links which support both exploratory and exploitative innovation processes. The evaluation shows that companies experience improvements in operational efficiency and innovation performance and enterprise value, while different industry sectors and geographical regions demonstrate distinct results. The relationship between digital initiatives and ambidexterity gets affected by leadership, environmental turbulence, and organizational agility (Qi et al. 2024; Jiang et al. 2024; Xiaokai Li et al. 2024; Zhao and Gao 2024; Liang et al. 2023; Ying and Jin 2023; Jöhnk et al. 2022; Xingong Li et al. 2024; Wang and Yan 2024; He and Wu 2024; Nour and Arbussà 2024).
Theoretical Frameworks of Ambidexterity	Research develops various theoretical frameworks which describe how organizations and their projects achieve dual operational capacity through structural organizational design and contextual environmental factors and their sequential practice of dual operational capacity and their hybrid operational methods. The frameworks provide solutions which organizations can use to manage their exploratory and exploitative activities in complex systems through the application of two fundamental concepts, which are paradox theory and dynamic capabilities. The academic literature investigates three different fields, which include decision-making theories and knowledge management and open innovation, to identify the mechanisms that lead to ambidextrous outcomes (Liu et al. 2012; Killen et al. 2023; Sun et al. 2023; Durugbo 2023; Sartori and Garrido 2023; Lieshout et al. 2021; Leybourne and Sainter 2014; Lastra and Sánchez-Gardey 2024).
Ambidexterity in Project and Portfolio Management	The research study examines project-level ambidexterity through the use of both agile and traditional project management methods while focusing on three main elements which include integration mechanisms and leadership styles and multiteam systems. The research demonstrates that organizations use project portfolio management practices to achieve ambidexterity between their opposed strategic objectives which leads to better project outcomes. The interaction between organizational ambidexterity and project ambidexterity establishes a vital relationship which organizations need to handle in order to succeed with their innovation efforts and adaptability requirements throughout their complex projects (Zhang et al. 2021; Binci et al. 2022; Sailer 2019; Petro et al. 2020; Lei et al. 2023; Ojiako et al. 2021; Alshawabkeh et al. 2020; Sun et al. 2018; Sohani and Singh 2017).
Innovation and Efficiency Outcomes	The practice of ambidexterity enables organizations to pursue dual objectives of developing new products while maintaining operational efficiency, which leads to enhanced business results and greater ability to adapt to changing conditions and sustainable development. The study proves that organizations which adopt ambidextrous innovation methods achieve better results in creating new technologies and business models when they face changing market environments. The research investigates how manufacturing and healthcare organizations achieve better performance results through their practice of ambidexterity (Park and Nahm 2023; Çelik and Uzunçarşılı 2023; Ma et al. 2022; Tamayo-Torres et al. 2017; Wang and Yan 2024; He and Wu 2024).
Dynamic Capabilities and Knowledge Management	The relationship between ambidextrous knowledge acquisition and digital transformation is influenced by dynamic capabilities which include alliance management and new product development. The implementation of knowledge management practices enables organizations to conduct both exploration and exploitation activities which help them cope with environmental changes while maintaining their innovative capacity. The ability of organizations to achieve ambidexterity depends on two primary factors which include external knowledge sourcing and organizational learning (Qi et al. 2024; Cheah and Tan 2023; Zhu and Li 2023; Alshawabkeh et al. 2020; Zhang 2024).
Industry-Specific Applications: Healthcare and Manufacturing	Sector-specific difficulties and their corresponding solutions are proven through ambidexterity research conducted in healthcare and manufacturing environments. Healthcare organizations achieve ambidexterity through their capability to manage operational functions and their capacity to implement digital technologies, whereas manufacturing organizations develop operational capabilities through their digital transformation initiatives and their innovation pathways and their organizational redesign efforts which help them achieve better business outcomes and market position according to research by (Xiao et al. 2025; Park and Nahm 2023; Roscoe and Blome 2019; Ma et al. 2022; Nour and Arbussà 2024).

Decision-Making and Managerial Capabilities in Ambidexterity	Research on how managers make decisions shows that standard expected utility models create obstacles for organizations which need to balance different innovations, therefore researchers should develop new decision-making models which include elements of potential regret. The ability of managers to control business operations together with their strategic decision-making skills, will determine how digital technologies and multiple innovation methods will affect business results (Glatin et al. 2018; Zhu and Li 2023; Zheng et al. 2023; Wang and Yan 2024).
Interplay of Multiple Digital Transformation Initiatives	Multiple digital transformation initiatives (DTIs) run simultaneously in organizations which results in hybrid ambidexterity development through structural and contextual transformations. The organization requires proper management of strategic alignment and governance methods and people and cultural elements to achieve its innovation goals while preventing redundant activities (Jöhnk et al. 2022).

(Source: Authors' own work)

4.2 Theoretical and Practical Implications

4.2.1 Theoretical Implications

- The synthesis of findings demonstrates that organizations use ambidexterity as a capability which enables them to conduct both exploration and exploitation activities through their entire structure and their individual project operations. The study extends existing theories by demonstrating that organizations require both contextual and structural components to achieve successful ambidexterity implementation in dynamic healthcare and manufacturing ecosystems (Liu et al. 2012; Binci et al. 2022; Sun et al. 2023).
- The reviewed literature highlights the critical role of digital transformation as both a driver and a moderator of ambidextrous innovation, suggesting that digital technologies reshape the balance and effectiveness of exploration and exploitation activities. The study presents a new understanding of ambidexterity because it shows how digital maturity affects two different aspects of time and organizational structure (Jiang et al. 2024; Xiaokai Li et al. 2024; Xingong Li et al. 2024).
- The combination of knowledge-based view and dynamic capabilities theory creates a strong theoretical framework. This theory explains how organizations use dual knowledge approaches and external knowledge acquisition methods to achieve successful digital transformation and innovation results. The researchers established a new theoretical framework which connects ambidexterity and knowledge movement with dynamic capabilities in production environments (Qi et al. 2024; Cheah and Tan 2023; Lieshout et al. 2021).
- The research demonstrates that leadership together with team diversity and management approaches play vital roles in creating ambidextrous innovation which occurs at project level. The research establishes how task conflict and team autonomy interact to affect expertise integration which subsequently impacts innovation results (Zhang et al. 2021; Zheng et al. 2023; Alshawabkeh et al. 2020).

The paradox and contingency viewpoints which study innovation portfolio management demonstrate that organizations need to handle their dual operational capabilities through specific systems that support their knowledge sharing process. The study establishes a theoretical framework for analyzing organizational dual operational capability which exists as an active, evolving process throughout various situations (Killen et al. 2023; Petro et al. 2020; Durugbo 2023).The literature also identifies gaps and ambiguities in the conceptualization of organizational ambidexterity in VUCA international contexts, calling for more rigorous frameworks that incorporate agility, knowledge management, restructuring, and experimentation to address volatility, uncertainty, complexity, and ambiguity (Lastra and Sánchez-Gardey 2024; Sartori and Garrido 2023).

4.2.2 Practical Implications

- The evidence shows that industry practitioners must create organizational and project frameworks which allow simultaneous development of exploratory and exploitative activities to achieve successful ambidexterity. The combination of cross-functional teams and diverse team members who receive freedom to operate results in improved ambidextrous innovation performance for infrastructure and manufacturing projects (Zhang et al. 2021; Katic et al. 2021; Lei et al. 2023).
- Digital transformation initiatives require management as simultaneous projects which together develop hybrid ambidexterity through both structural and contextual transformations. Organi-

zations must manage their core units through digital transformation initiatives to establish effective operational procedures which increase their innovation capacity and operational performance (Jöhnk et al. 2022; Castilho Junior et al. 2023; Johnson et al. 2022). The manufacturing and healthcare sectors obtain advantages from ambidextrous innovation capabilities which digital technologies and knowledge management and dynamic capabilities provide. Firms should allocate resources to develop ambidextrous knowledge systems while using digital collaboration tools to improve their incremental and radical innovation processes (Qi et al. 2024; Zhang and Hao 2024; Park and Nahm 2023).

- Organizations use project portfolio management to achieve project-level ambidexterity because this method helps them fulfill two different strategic objectives while running their dual research and operational activities. The process requires integrated leadership systems together with agile project management techniques which enable handling both planned and unplanned innovation development (Sailer 2019; Petro et al. 2020; Binci et al. 2022).
- Policymakers and organizational leaders should recognize the moderating role of ambidextrous innovation in enhancing the positive impacts of digital transformation on firm performance and sustainability. The research recommends customized digital strategies which address regional and industrial and organizational differences for achieving optimal performance outcomes (Ying and Jin 2023; Wang and Yan 2024; He and Wu 2024).

Table 2: Gaps and Future Research Directions

Gap Area	Description	Future Research Directions
Conceptual clarity and operationalization of ambidexterity	The definitions and operational methods of ambidexterity show significant differences which result in inconsistent applications of theoretical frameworks and empirical studies that extend to both organizational and project execution.	Researchers need to create complete operational definitions together with measurement scales that measure their work at different levels which should apply to all operational research within digital transformation environments. The validation studies need to examine multiple industries for their research.
Cross-level dynamics between organizational and project ambidexterity	Scientists have conducted only a few empirical studies which demonstrate how organizational ambidexterity affects project-based ambidexterity and how project-based ambidexterity affects organizational ambidexterity in the context of digital transformation.	The researchers need to conduct multi-level empirical research over an extended period to create a model which shows how organizational and project ambidexterity interact through feedback loops while digital transformation acts as a controlling element.
Integration of digital transformation with ambidexterity theories	The existing ambidexterity frameworks need digital transformation systems to achieve their full potential because their current state lacks proper digital transformation system integration.	The researchers need to build interactive theoretical models which link digital transformation elements with their ambidexterity systems to achieve results in both innovation and efficiency.
Leadership and team dynamics in digital ambidexterity	Researchers have conducted limited large-scale quantitative studies to investigate how different leadership styles and team diversity patterns and knowledge management practices affect ambidexterity results in both digital environments and project settings.	The researchers will create mixed-method research designs to measure how leadership behaviors and team diversity and knowledge integration work together to impact ambidextrous innovation throughout digital transformation. Ambidextrous leaders have psychological effects which need research.
Managing multiple concurrent digital transformation initiatives (DTIs)	The research about how multiple DTIs work together with hybrid ambidexterity remains incomplete because their combined effects and management methods need further study.	The researchers will use case studies and surveys across different industries to examine how organizations use their management practices and decision-making processes to achieve hybrid ambidexterity through effective management of multiple digital transformation initiatives.
Sectoral and regional heterogeneity in ambidexterity and digital transformation	The current understanding of how ambidexterity and digital transformation work together with contextual factors in different sectors and regions needs further development because existing studies only compare two specific sectors.	The researchers will conduct studies across different sectors and regions to find out which institutional and cultural and environmental factors influence organizations' abilities to achieve ambidexterity together with their efficiency of digital transformation.

(Source: Authors' own work)

5 DISCUSSION AND CONCLUSION

Research indicates that the relationship between organizations and their projects is characterized by the dynamics and interdependence that help to develop the needs of innovation and efficiency and adaptive capacities in the context of technology advancement in healthcare and manufacturing. Organizational ambidexterity provides organizations with the ability to allocate their time between two distinct activities: explorative and exploitative activities. The relationship between the two concepts demonstrates complexity since the research proves that effective ambidexterity implementation is possible only when organizations create proper structural design patterns that allow combining different kinds of ambidexterity in accordance with organizational and project needs. The studies of mechanisms of multi-level integration, such as project portfolio management and organizational design, indicate their importance in managing organizational capabilities; however, the lack of evidence of concrete connections between these two levels of research creates significant research gaps.

Digital transformation can be considered as the key driver of both ambidextrous innovation and efficient operation since it helps organizations to enhance their capabilities, especially knowledge sharing, and achieve the balance between exploration and exploitation. The relationship between digital technologies and organizational performance is determined by three important factors which are organizational learning capabilities, leadership capabilities, and resource management practices. The impact of digital transformation on innovation outcomes is non-linear and depends on the following contextual factors: environmental turbulence, managerial power and organizational culture. In view of rapidly changing technological and uncertain business environment of various industries, it is important to use management approaches based on paradoxes and dynamics.

Such factors as leadership and team dynamics act as important mediating variables which enable companies and their projects to become ambidextrous. The presence of a variety of cross-functional teams along with such leadership styles as empowerment and directing and the use of agile approach leads to enhanced innovative performance and project success. The interaction of social and behavioral processes with the digital transformation process should be tested empirically since its effects have not been identified yet. The operationalization of ambidexterity varies from industry to industry; for example, the need to implement paradoxical management in order to balance collaboration and control exists in healthcare organizations.

To conclude, there have been made significant advances in the existing theoretical studies on ambidexterity. However, the practice related to the digital transformation process as well as industrial application is still in its infancy. There is a necessity for multi-level empirical research which would describe the link between organizational and project ambidexterity and consider digital transformation process as a new emerging condition. Such a study would contribute to academic research and provide practical approaches to the management of ambidexterity in a rapidly changing digitalized environment.

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1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

COMPARISON OF CHALLENGES IN THE IMPLEMENTATION OF BLITZ PROJECTS IN THE PUBLIC AND PRIVATE SECTORS

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ABSTRACT

Organizations increasingly implement projects under extreme time pressure as technologies evolve, markets change, and emergencies arise. Blitz projects are characterized by accelerated delivery in response to urgent societal or organizational challenges, yet their implementation remains insufficiently examined across different institutional settings. This study compares the challenges of implementing blitz projects in public- and private-sector contexts. It applies a qualitative multi-method design combining a structured literature review, comparative case study analysis, and a focus-group interview with five experienced project managers from public- and private-sector organizations. The analysis examines organizational structures, resource allocation, stakeholder engagement, operating environments, decision-making, and implementation challenges. Public-sector blitz projects, including emergency hospitals established during the COVID-19 pandemic, are shaped by crisis mandates, centralized coordination, regulatory constraints, civic mobilization, and the need to deploy substantial resources rapidly. Private-sector initiatives, illustrated by accelerated vaccine development, are driven by strategic goals, innovation, and market responsiveness and therefore require agile management, cross-functional collaboration, rapid decision-making, substantial at-risk investment, and continuous regulatory alignment. Despite these contextual differences, the findings identify common success factors across both sectors: leadership commitment, stakeholder engagement, organizational agility, effective resource mobilization, clear communication, empowered decision-making, and the capacity to adapt project structures under severe time constraints. The study contributes to the emerging body of knowledge on blitz projects by extending their application beyond crisis-response environments and examining their relevance to innovation-oriented business projects. The findings indicate that blitz project practices cannot be transferred uniformly between sectors; instead, organizations must adapt governance, stakeholder-management, and resource-allocation mechanisms to their institutional context while preserving the shared managerial capabilities required for accelerated delivery.

Keywords: *blitz projects, accelerated project delivery, public sector, private sector, project management*

1 INTRODUCTION

Existing research demonstrates that project-based approaches are increasingly used to address complex societal challenges and growing environmental complexity, while crisis-response projects developed during pandemics and natural disasters illustrate the importance of rapid project environments (Shenhar and Dvir 2007; Ika and Munro 2022; Lechler et al. 2022).

Project schedule compression and project crashing remain important topics within project management research. However, these concepts do not fully capture the specific characteristics of blitz projects, which require simultaneous management of extreme time pressure, resource mobilization, stakeholder coordination, and organizational flexibility. Research on blitz projects remains limited and is primarily associated with crisis-response initiatives and emergency construction projects.

Recent studies have examined the rapid construction of emergency hospitals and other accelerated projects implemented during the COVID-19 pandemic. These studies identified the importance of extreme schedule strategies, leadership support, stakeholder engagement, resource mobilization, and organizational agility for successful project delivery under severe time constraints (Luo et al. 2020; Li et al. 2024, 68–85; Ying et al. 2025). Collectively, they emphasize the need for further research into blitz project management and its applicability beyond emergency-response environments. Earlier research also showed a significant research gap in the application of blitz project principles within business and industry contexts (Mirić Horvatić 2024).

Although previous studies have examined crisis projects, temporary organizations, project pace, and rapid-response initiatives, limited attention has been devoted to comparing blitz project implementation across public and private sector environments. Existing research is predominantly focused on emergency-response projects, healthcare infrastructure, and pandemic-related initiatives (Fang et al. 2020; Lewis et al. 2023; Li et al. 2024). Consequently, further research is needed to determine whether blitz project principles can be systematically applied within competitive business environments where innovation, time-to-market, and strategic responsiveness represent critical success factors.

This paper addresses this research gap by providing a comparative analysis of blitz project implementation in public-sector emergency hospital projects and private-sector pharmaceutical projects. Drawing on a literature review, comparative case study analysis, and a focus-group interview with experienced project managers, the study examines differences in organizational structures, stakeholder engagement, resource allocation mechanisms, and implementation challenges while identifying common factors that contribute to successful blitz project delivery across sectors.

2 PURPOSE AND GOALS

The purpose of this study is to provide a comparative analysis of the challenges associated with implementing blitz projects in the public and private sectors. The main goal is to identify key implementation challenges and generate insights that may support project managers and organizations operating in highly time-constrained environments.

The research is guided by the following question: What are the unique challenges faced in implementing blitz projects in public versus private sectors?

The study aims to clarify differences in organizational context, management approaches, resource allocation, stakeholder engagement, and implementation challenges across sectors while contributing to both academic knowledge and project management practice.

3 METHODS

This study adopted a qualitative multi-method research design combining a literature review, comparative case study analysis, and a focus-group interview. The integration of these methods enabled a comprehensive comparison of blitz project implementation challenges in public- and private-sector environments.

The study is grounded in the constructivist research paradigm, which assumes that knowledge about organizational phenomena is developed through the experiences and interpretations of individuals. Since blitz projects remain a relatively underexplored phenomenon within project manage-

ment research, a qualitative approach was considered most appropriate for exploring their characteristics, implementation challenges, and future applicability within business and industry (Cicmil et al. 2006; Creswell and Creswell 2023). According to Creswell and Creswell (2023), qualitative research is particularly appropriate when researchers seek to understand complex phenomena in their natural setting and from the perspective of individuals involved. Similarly, Cicmil et al. (2006) emphasize the value of qualitative approaches in project management research when investigating emerging organizational practices and managerial experiences.

The research design employed methodological triangulation through the integration of multiple data sources. Triangulation is recognized as an effective approach for improving credibility, trustworthiness, and completeness of qualitative findings by examining a phenomenon from different perspectives and sources of evidence (Denzin 1978; Schlunegger et al. 2024).

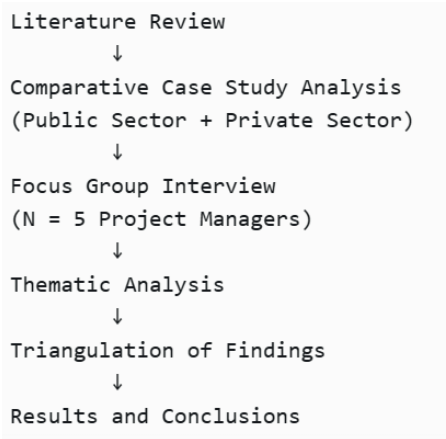
3.1 Research Design Justification

A literature review was selected as the first research method because it enables the systematic identification, analysis, and synthesis of earlier research findings. Literature reviews are particularly useful in emerging research areas where existing knowledge remains fragmented and where further theoretical development is required (Snyder 2019). The literature review was therefore used to identify current knowledge related to project pace, crisis projects, schedule compression, and blitz projects. A case study approach was selected because it enables the investigation of contemporary phenomena within their real-life context (Yin 2018). A focus-group interview was selected as the primary empirical data-collection method because it enables the collection of multiple practitioner perspectives while encouraging interaction among participants. This method is particularly suitable for exploring emerging concepts and understanding perceptions, expectations, and experiences shared among professionals (Krueger 1994; Krueger and Casey 2000).

3.2 Research Process

The research process consisted of three sequential stages. First, a structured literature review was conducted to identify existing knowledge on project schedule management, project pace, crisis projects, and blitz projects. The review enabled the identification of key concepts, theoretical foundations, and research gaps (Snyder 2019). Second, a comparative case study approach was applied to analyze examples of blitz projects in both public and private sector environments. Attention was given to emergency hospital projects during the COVID-19 pandemic and the Pfizer-BioNTech vaccine development program. The goal was to identify organizational structures, resource allocation mechanisms, stakeholder engagement approaches, and managerial practices supporting accelerated project execution. Third, a focus-group interview was conducted to obtain practitioner perspectives (Figure 1).

Figure 1: Research process



(Source: Author's own elaboration)

3.3 Focus Group Participants

The focus group consisted of five experienced project managers selected through purposive sampling. Eligibility required at least ten years of project management experience. Three participants represented private-sector organizations, and two represented public-sector organizations. Collectively, they brought experience from information technology, healthcare, pharmaceuticals, and pharmaceutical marketing, enabling comparison across sectors and professional settings.

The focus group was intentionally designed as a mixed-sector panel to compare perspectives from public- and private-sector practitioners and support triangulation of the findings.

Participation was voluntary, and all responses were anonymized to protect confidentiality and support open discussion. The focus-group interview was conducted face to face in Zagreb, Croatia, in October 2025, as a single 90-minute semi-structured session. The discussion followed predefined research themes while allowing interaction among participants. The researcher documented the session through detailed notes, which were subsequently organized, coded, and interpreted using thematic analysis.

Participants discussed six predefined themes: organizational structure, stakeholder engagement, resource allocation, communication, leadership support, and challenges associated with blitz projects.

The findings from the literature review, comparative case study analysis, and focus-group interview were integrated through thematic analysis. Following Braun and Clarke (2006), the researcher reviewed the collected material, organized observations according to recurring concepts, coded evidence related to the six predefined themes, compared patterns across the three research stages, and interpreted convergent and divergent findings. This process enabled the study to distinguish sector-specific implementation challenges from success factors that appeared across both public- and private sector contexts. Table 1 presents the triangulation of findings across the three research methods.

Table 1: Triangulation of Findings across Research Methods

Main Finding	Literature Review	Case Study	Focus Group
Blitz project characteristics	✓	✓	✓
Organizational structure	✓	✓	✓
Resource allocation	✓	✓	✓
Stakeholder engagement	✓	✓	✓
Communication mechanisms	✓	✓	✓
Top-management support	✓	✓	✓
Future applicability in industry	✓	✓	✓

(Source: Author's own elaboration)

3.4 Research Contribution

This study contributes to the emerging body of knowledge on blitz projects in three ways. First, it provides a comparative analysis of blitz projects across public- and private sector environments. Second, it integrates evidence obtained through a literature review, comparative case study analysis, and a focus-group interview, applying methodological triangulation to a relatively underexplored phenomenon. Third, the study identifies a set of common success factors that appear transferable across both crisis-response and business-oriented project environments. These findings contribute to both project management theory and managerial practice.

4 RESULTS

4.1 Key Differences in Blitz Project Implementation in the Public and Private Sectors

The findings presented in this section originate primarily from the literature review and comparative analysis of previously published studies. The purpose of this section is to show structural and managerial differences in blitz project implementation between public and private sector environments.

In the public sector, blitz projects such as emergency field hospitals were primarily motivated by urgent societal needs and mandates, with execution shaped by top-down command, centralized resource allocation, and crisis-driven stakeholder mobilization. These initiatives relied on large-scale coordination between governmental units, rapid repurposing of infrastructure, and community solidarity, often operating under high uncertainty and bureaucratic constraints (Fang et al. 2020; Li et al. 2024).

In contrast, private sector initiatives were driven by strategic goals, innovation, and market responsiveness, requiring agile management and rapid decision-making. For instance, the pharmaceutical industry's development of COVID-19 vaccines exemplified how business priorities—such as being first-to-market, sustaining competitiveness, and driving breakthroughs—needed cross-functional teamwork, bold at-risk investments, and adaptive project structures. Here, agility, continual iteration, and swift executive support underpinned the ability to compress development cycles without sacrificing regulatory compliance or quality (Agrawal et al. 2021; Lewis et al. 2023). Table 2 summarizes the main differences between blitz projects in public and private sector environments.

Table 2: Differences between Blitz Projects in the Public and Private Sectors

Factor	Public Sector (Emergency Hospitals)	Private Sector (Pharma/Vaccine)
Primary Drivers	Societal need, crisis mandates, policy directives	Strategic goals, innovation, market responsiveness
Decision-Making	Centralized, hierarchical, sometimes bureaucratic	Agile management, empowered project leaders, rapid/iterative decisions
Organization	Multi-tiered, ad hoc crisis teams	Cross-functional/matrix structures, alliances, task forces
Resource Allocation	Centralized, donations, public assets	At-risk investments, supply chain optimization, proprietary resources
Stakeholder Engagement	Civic mobilization, political/media scrutiny	Regulatory agencies, partners, investors, global market
Environment	Policy flexibility, legal overrides, chaotic/uncertain	Highly regulated, competitive, market-driven
Key Challenges	Bureaucratic delay, resource friction, operational waste	Supply chain fragility, innovation under pressure, managing compliance at speed

(Source: Author's own elaboration based on Fang et al. 2020, Li et al. 2024, Lewis et al. 2023, and comparative case study analysis)

As shown in Table 2, public sector blitz projects often prioritize rapid societal impact through mandated collaboration, while private sector blitz projects emphasize strategic positioning, innovation, and agile responses to dynamic markets.

4.2 Key Challenges in the Public and Private Sectors

The findings presented in this section derive from the comparative case study analysis of public-sector emergency hospital projects and private-sector vaccine development projects. The section aims to highlight sector-specific challenges identified through empirical comparison.

The comparative case study analysis showed distinct challenges in public and private sector blitz projects, as summarized below and in Table 3.

4.2.1 Public Sector (Emergency Hospitals)

- Often run under emergency mandates and centralized authority, which can accelerate action but also create bureaucratic delay and coordination issues between multiple agencies.

- Resource allocation relies on government stocks, donations, and rapid mobilization of labor, but logistical friction and inefficiency can occur due to the scale and urgency.
- Team structures are temporary, multi-tiered, and may suffer from rapidly built trust and unclear roles.
- Stakeholder engagement centers on civic mobilization and public/media scrutiny; maintaining legitimacy and transparency is vital but challenging.
- Quality and functionality may be sacrificed for speed, resulting in post-project fixes and operational deficiencies.
- Operating environments are chaotic and uncertain, requiring frequent project scope adaptations.

4.2.2 Private Sector (Pharma/Vaccine Development)

- Driven by strategic goals, innovation, and market responsiveness, requiring agile management and rapid decision-making.
- Resource allocation involves large at-risk investments, proprietary materials, and supply chain optimization, but faces fragility and competition for global resources.
- Organizational structures are cross-functional/matrix-based, demanding empowered leadership and teamwork across functions and partners.
- Stakeholder engagement is multi-layered—regulatory agencies, partners, investors, and markets—which must be coordinated for compliance and trust.
- High safety and quality standards must be maintained despite compressed development cycles; speed must not compromise regulatory requirements.
- The environment is highly regulated and competitive; projects need to adapt quickly to scientific, legal, and market changes.

Key challenges in the public and private sectors are summarized in Table 3.

Table 3: Key Challenges in the Public and Private Sectors

Challenge Area	Public Sector (Emergency Hospitals)	Private Sector (Pharma/Vaccine Development)
Regulation	Emergency overrides, but political/public accountability	Regulatory compliance (FDA/EMA), cannot bypass safety/quality
Resource Allocation	Central mandate, donations, temporary labor, logistical friction	„At-risk" investments, fragile supply chains, proprietary resources
Team Structure	Top-down, multi-tier crisis teams, variable trust	Matrix/cross-functional, empowered project managers, alliance partnerships
Speed vs. Quality	Function > aesthetics, post-construction fixes common	High quality/safety mandatory, phase compression risky
Stakeholder Engagement	Public/civic mobilization, political/media scrutiny	Internal, regulatory, partner, and investor management; must maintain multi-country alignment
Innovation Approach	Modular construction, re-use existing assets	Platform technology, concurrent/parallel R&D, digital acceleration
People & Morale	Volunteer burnout, civic spirit, rapid trust-building	Burnout risk, distributed teams, change fatigue
Environment	Chaotic, uncertainty-driven, policy flexibility in emergencies	Competitive, compliance-driven, evolving science and market

(Source: Author's own elaboration based on literature review and comparative case study findings)

4.3 Focus-Group Findings on Blitz Project Implementation Challenges

The findings presented in this section are based on a focus-group interview with experienced project managers and serve to confirm and contextualize findings obtained through the literature review and comparative case study analysis.

Public sector blitz projects focus on rapid societal impact through centralized coordination, but must contend with bureaucracy, logistics, and stakeholder pressures in chaotic contexts.

Private sector blitz projects are oriented toward strategic goals, innovation, and market success, demanding agile organizational approaches, high investment, and rigorous compliance within competitive and uncertain environments.

4.3.1 Organizational Structure

- Public Sector:
  - Utilizes top-down, hierarchical structures—centralized "war room" style command, often involving special taskforces created for crisis response (e.g., health bureaus, state-owned construction companies for field hospitals).
  - Decision-making power is concentrated at high administrative levels, facilitating fast approvals but sometimes causing coordination problems and bureaucratic delays.
  - Teams are *ad hoc* and temporary, requiring quick establishment of trust and clarity of roles.
- Private Sector:
  - Private-sector projects rely on agile, cross-functional, and sometimes matrix structures. Project managers and team leaders are empowered to make rapid decisions.
  - May include external partnerships and joint ventures (e.g., Pfizer-BioNTech alliance for vaccine development), enhancing flexibility and access to diverse expertise.
  - Rapid creation of task forces with domain experts from different functions, ensuring broad collaboration and problem-solving capacity.

4.3.2 Resource Allocation

- Public Sector:
  - Governments can repurpose public infrastructure and deploy large labor contingents in short periods.
  - Logistics are complex; while resource scale is large, efficiency may suffer from chaotic deployment and procurement bottlenecks, especially under lockdown or emergency conditions.
  - Reliant on pre-existing government stockpiles but often face gaps and misalignments in actual needs versus available resources.
- Private Sector:
  - Requires large up-front "at risk" investments in research, development, and manufacturing (e.g., scaling up mRNA vaccine production prior to regulatory approval).
  - Supply chains must be quickly established and scaled; proprietary materials (like lipids, vials) may be scarce or require accelerated procurement.
  - Risks are higher for costs if the project fails, and global logistics present challenges.

4.3.3 Stakeholder Engagement

- Public Sector:
  - Major reliance on civic mobilization, engaging volunteers, accepting donations, involving local communities in implementation.
  - Stakeholder landscape includes government bodies at multiple levels, media, public, and affected populations.
  - Engagement is usually mandated or top-down, but maintaining public trust and legitimacy under intense scrutiny is a constant challenge.
- Private Sector:
  - Stakeholders include internal project teams, external partners, regulatory agencies, investors, and customers/markets.
  - Engagement is structured, strategic, and often global—requires continuous regulatory communication, investor updates, and alignment with international partners.
  - Maintaining confidence and trust is critical given high uncertainty, and stakeholder expectations must be managed dynamically throughout project execution.

4.3.4 Operating Environment

- Public Sector:
  - Characterized by crisis, uncertainty, and frequent changes in project scope or requirements. Legal/policy flexibility is higher during declared emergencies, enabling rapid repurpose and improvisation.

- Projects must adapt 'on the fly,' often facing infrastructure limits and situational unpredictability (e.g., changing spread of disease, shifting government priorities).

- Private Sector:
  - Highly regulated and competitive, with legal and quality standards that cannot be compromised, even under urgency.
  - Projects must stay responsive to market shifts, competitor actions, evolving scientific knowledge, and compliance requirements.
  - Operating in a globalized and innovation-driven environment requires continual adaptation and rigorous risk management.

Table 4: Development of Codes, Categories, and Themes from Focus-Group Notes

Initial Codes from Focus-Group Notes	Analytical Category	Theme
centralized approval; multiple agencies; unclear roles	Governance and coordination	Organizational structure
at-risk investment; scarce materials; procurement bottlenecks	Resource pressure	Resource allocation
public scrutiny; regulatory alignment; partner expectations	Stakeholder complexity	Stakeholder engagement
scope changes; evolving science; market shifts	Continuous adaptation	Operating environment
executive support; empowered decisions; rapid communication	Enabling capabilities	Cross-sector success factors

(Source: Author's own elaboration based on focus-group notes)

The researcher organized the detailed session notes into initial codes, broader analytical categories, and themes. Table 4 presents this coding progression. Because the focus-group discussion was documented through detailed researcher notes rather than a verbatim transcript, participant quotations or reconstructed paraphrases are not reported.

4.4 Summary of Findings by Research Method

The literature review confirmed that blitz projects are primarily associated with crisis-response situations, emergency interventions, and accelerated project delivery under severe time constraints. Existing literature also shows that research on blitz projects remains limited, and that additional theoretical and practical investigation is required. The case study analysis showed how accelerated decision-making, stakeholder collaboration, parallel execution of activities, and strong leadership support contribute to successful project delivery in both public and private sector environments. The focus-group findings confirmed the practical relevance of these factors. Participants highlighted top-management support, stakeholder engagement, resource availability, communication effectiveness, and organizational capabilities as critical conditions for successful blitz project implementation. Together, the findings from all three research methods support the argument that blitz project principles may be applicable beyond traditional crisis-response situations.

5 DISCUSSION

The comparative analysis shows that the principal differences between public- and private-sector blitz projects arise from their mandates, governance structures, resource-allocation mechanisms, and stakeholder environments. Public-sector projects prioritize urgent societal impact through centralized crisis coordination, whereas private-sector projects pursue strategic and innovation goals through agile, cross-functional structures. Across both contexts, successful implementation depends on leadership commitment, rapid decision-making, stakeholder engagement, organizational agility, and effective resource mobilization.

The results reflect the fundamental differences in mission, structure, and operating context between the public and private sectors during blitz projects:

- Public sector blitz projects (e.g., emergency hospitals) are shaped by crisis urgency, top-down mandates, and civic mobilization. This leads to rapid action but also coordination challenges, resource inefficiency, and potential quality trade-offs. The environment is chaotic, requiring ad hoc plans and continual adaptation, which explains why quality and long-term sustainability may be compromised for immediate impact.

- Private sector blitz projects (e.g., vaccine development) are driven by strategic goals, innovation, and market needs, demanding agile management and rapid decision-making. Intense competition and high regulatory standards mean that speed must be balanced with robust quality control, resource risk management, and stakeholder alignment. Cross-functional and global teams face the challenge of quick, compliant innovation under pressure.

5.1 Theoretical Implications

The findings extend existing blitz project literature by showing that several success factors previously identified in crisis-response environments are also relevant to private-sector innovation projects. The importance of rapid resource mobilization, stakeholder coordination, parallel execution, and leadership support is consistent with evidence from emergency hospital projects (Fang et al. 2020; Luo et al. 2020; Li et al. 2024, 68–85; Ying et al. 2025). The private-sector findings also align with research on accelerated vaccine development, which emphasizes cross-functional collaboration, substantial at-risk investment, regulatory coordination, and rapid executive decision-making (Agrawal et al. 2021; Lewis et al. 2023, 640–647). The comparison therefore indicates that the institutional mechanisms differ across sectors, but leadership commitment, stakeholder engagement, organizational agility, and effective resource mobilization remain common determinants of accelerated project delivery.

5.2 Practical Implications

For practitioners, the findings suggest that organizations intending to implement blitz projects should establish empowered decision-making structures, ensure resource availability, strengthen stakeholder communication mechanisms, and maintain organizational flexibility. Public-sector organizations may benefit from agile management techniques, while private-sector organizations may learn from public-sector crisis coordination and large-scale resource mobilization practices. These findings highlight the importance of adapting blitz project practices to specific organizational contexts while maintaining core success factors such as leadership support, stakeholder engagement, organizational agility, and rapid decision-making.

The results also highlight that there is no one-size-fits-all approach: strategies must be tailored to organizational structures, decision-making cultures, and external constraints.

6 RESEARCH LIMITATIONS

This study has several limitations. First, the focus-group sample consisted of only five participants selected from a single country, which limits the generalizability and cross-cultural transferability of the findings. Second, the focus-group session was documented through detailed researcher notes rather than a complete audio-recorded transcript; consequently, the analysis could not reproduce participants' statements verbatim or examine all nuances of the discussion. Third, the empirical evidence was based on a limited number of illustrative blitz-project examples, primarily associated with the COVID-19 period. Fourth, the study relied predominantly on qualitative methods and therefore does not provide statistical validation of the findings. Finally, blitz projects remain a relatively new and underdeveloped concept within project management literature, and the availability of comparable empirical studies was limited. The findings should therefore be interpreted as an exploratory contribution to theory development rather than as definitive or universally generalizable conclusions.

Future research should include larger international samples, additional public-sector and private-sector case studies, and quantitative validation of factors influencing blitz project success. Future studies could also explore the development of a dedicated implementation framework for blitz projects within business and industry.

7 CONCLUSION

This study demonstrates that public- and private-sector blitz projects face different operational and institutional challenges but depend on a common set of managerial capabilities. Public-sector projects require rapid coordination across complex governance and stakeholder systems, where-

as private-sector projects must combine speed and innovation with regulatory compliance and market responsiveness. In both settings, leadership commitment, stakeholder engagement, rapid decision-making, organizational agility, clear communication, and effective resource mobilization are central to successful implementation. These findings extend the relevance of blitz project principles beyond crisis response and indicate their potential value for innovation-oriented business projects. In practice, organizations should adapt governance, resource allocation, and stakeholder-management mechanisms to their sector while preserving these shared success factors. Future research should test the findings through larger international samples and develop sector-specific implementation frameworks.

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SOFT FACTORS AND VALUE CREATION IN HIGH-PERFORMING TECHNICAL ORGANISATIONS EXPOSED TO PROJECTIFICATION

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ABSTRACT

Engineering-driven organisations (EDOs), particularly in Engineering, Procurement and Construction (EPC) environments, rely heavily on project-based modes of organising their activities. While strong technical expertise and established professional practices underpin their operational performance, increasing projectification may also reshape how professionals interpret strategic expectations and contribute to organisational value creation. This paper approaches projectification as an analytical lens for examining how professionals in technical organisations experience projectified work environments, how they interpret strategic expectations, and how soft organisational factors influence their professional practices. Drawing on literature on projectification, project value creation and organisational behaviour, the study explores the human dimensions of value creation in project-intensive environments. Empirical insights are derived from semi-structured interviews with professionals working in an EPC organisation. The findings indicate that increasing project pressure, resource constraints and growing project complexity require professionals to adapt their work practices and assume broader coordination responsibilities. The results further highlight the importance of soft organisational factors such as communication, leadership support and motivational dynamics in enabling professionals to sustain engagement and contribute to organisational value creation. The study contributes to a better understanding of how projectification shapes professional work practices and how professionals interpret and respond to strategic expectations, highlighting the importance of organisational conditions that support collaboration, motivation and professional engagement in engineering-driven environments.

Keywords: *projectification, engineering-driven organisations, management, soft factors, organisational value creation*

1 INTRODUCTION

Engineering-driven organisations, particularly those operating in Engineering, Procurement and Construction (EPC) environments, rely heavily on project-based modes of organising their activities. Project-based organisations (PBOs) are commonly defined as organisations that apply project management processes as their primary business processes to accomplish their business goals (Turner 2009; Müller et al. 2024). In such settings, projects become the principal mechanism through which strategy is implemented, work is coordinated and organisational objectives are achieved. It should be emphasised that this shift does not refer to individual projects or even portfolios of projects, but to a broader organisational transformation in which temporary project structures become a dominant mode of organising work. This transformation, commonly conceptualised as projectification, reflects the increasing interaction between permanent organisational structures and temporary project-based arrangements, shaping how work is coordinated and how organisational value is created.

However, engineering-driven organisations typically exhibit a more complex structure than the classical understanding of project-based organisations. In addition to externally delivered projects, they maintain strong functional structures responsible for engineering expertise, technological development and internal organisational initiatives. As highlighted in governance research, activities in project-based organisations frequently span both the functional and the project-oriented parts of the organisation (Müller et al. 2024). This duality reflects the coexistence of permanent organisational structures and temporary project arrangements, requiring coordination across multiple organisational levels.

This coexistence of functional and project logics creates an organisational environment in which project-based ways of working gradually extend beyond formal project structures and begin to shape broader organisational behaviour. In EPC environments, projects often represent the core mechanism of value delivery to external clients, while internal organisational units simultaneously operate their own improvement, development and innovation initiatives. In such contexts, project-based structures increasingly influence how work is organised, coordinated and evaluated across the organisation.

This phenomenon has been widely discussed in the literature under the concept of projectification. Projectification generally refers to the growing reliance on projects as a dominant form of organising work and coordinating activities across different domains of society and organisations (Midler 1995; Lundin et al. 2015). An integrative review by Jacobsson and Jałocha (2021) identifies four main perspectives through which projectification has been studied: the projectification of society, organisations, work and individuals. Among these perspectives, the projectification of organisations and work is particularly relevant for engineering-driven environments, where project-based coordination increasingly shapes professional roles, communication patterns and decision-making processes.

Rather than treating projectification solely as a structural transformation, this study approaches projectification as an analytical lens for examining how project-based logics influence human behaviour, collaboration patterns and value creation within engineering-driven organisations (Jacobsson and Jałocha 2021; Jensen et al. 2016). In highly technical environments, where professional identities are strongly shaped by engineering expertise and technical rationality, projectification may influence not only organisational structures but also interpersonal dynamics, leadership practices and the ways professionals engage with strategic objectives.

As project-based modes of organising expand across organisations, increasing attention has been directed toward understanding how projects contribute to organisational value creation. Contemporary project management research increasingly emphasises that the success of projects should not be evaluated solely through traditional performance indicators such as time, cost and scope, but rather through their contribution to broader organisational value (Laursen and Svejvig 2016). Empirical research in engineering projects further demonstrates that project success involves multiple dimensions, including technical performance, stakeholder satisfaction and organisational outcomes (Radujković et al. 2021). More recent work also highlights the importance of explicitly identifying and managing project benefits to enhance value creation (Zwikael 2024).

In engineering-driven organisations, where projects represent the primary mechanism through which technical expertise is translated into delivered solutions, value creation depends not only on technical capabilities but also on how professionals collaborate, communicate and coordinate their efforts within complex project environments. Consequently, increasing attention has been directed towards the softer organisational factors that influence professional interaction and decision-making in project settings. Leadership practices, communication patterns, organisational culture and interpersonal relationships may significantly shape how professionals interpret organisational expectations and engage with project goals.

In project-intensive environments, professionals often develop strong technical identities and professional mindsets that influence how they perceive autonomy, responsibility and their role within project structures. Projectified forms of organising may therefore shape how knowledge workers understand their professional contribution and navigate organisational pressures (Kalff 2017). From a motivational perspective, Self-Determination Theory suggests that individuals are more likely to engage in meaningful and sustained contributions when their needs for autonomy, competence and relatedness are supported within organisational environments (Deci et al. 2017; Behzadnia and Deci 2025). These perspectives highlight the importance of examining the human and motivational dimensions of project work when analysing value creation in technical organisations.

Despite growing recognition that projects contribute not only to delivery performance but also to broader strategic and organisational outcomes, empirical insights into how professionals in engineering-driven organisations interpret their role in such transformations remain limited. Prior research has highlighted the importance of project governance and benefit management in supporting organisational strategy implementation (Musawir et al. 2017), as well as the role of social capital, knowledge integration and learning in shaping performance within project-based organisations (Prieto-Pastor et al. 2018). Studies have also examined how project-based organisations balance exploration and exploitation in response to increasing complexity and change (Eriksson 2013), and how dynamic capabilities are enacted across multiple organisational levels within project environments (Barbosa and Carvalho 2024).

However, less is known about how professionals in engineering-driven and EPC environments make sense of growing strategic expectations related to value creation, and how soft organisational factors shape their professional practices within increasingly projectified work settings. This study addresses that gap through an exploratory qualitative inquiry into how professionals interpret these expectations and adapt their practices in contributing to organisational value creation.

This study therefore asks:

How do professionals in engineering-driven organisations interpret strategic expectations within projectified work environments, and how do soft organisational factors shape their professional practices in contributing to organisational value creation?

By addressing this question, the study integrates insights from projectification, organisational behaviour and value creation in order to examine how professionals interpret and respond to increasing strategic expectations in projectified environments. The remainder of the paper develops this perspective through the definition of the study's purpose and goals, the presentation of the research design and the analysis of empirical findings.

2 PURPOSE AND GOALS

The purpose of this study is to explore how professionals in engineering-driven organisations interpret strategic expectations and adapt their professional practices within increasingly projectified work environments in order to contribute to organisational value creation. In highly project-intensive technical contexts, professionals operate at the intersection of strong technical identities, increasing strategic expectations and complex project coordination requirements. Understanding how professionals interpret and respond to these conditions provides important insights into the human dimensions of value creation in project-based technical organisations.

Existing research has addressed the role of project governance and benefit management in supporting organisational strategy implementation (Musawir et al. 2017), as well as the importance of

social capital, knowledge integration and learning in project-based organisations (Prieto-Pastor et al. 2018). More recent work also highlights the multilevel nature of dynamic capabilities in project environments (Barbosa and Carvalho 2024). However, less attention has been given to how professionals interpret these organisational conditions and translate them into everyday practices within engineering-driven contexts.

Building on literature on projectification, project value creation and organisational behaviour, this study focuses on the role of soft organisational factors in shaping how professionals interpret organisational expectations and adapt their practices within projectified environments. Particular attention is given to how leadership practices, communication patterns, organisational culture and motivational conditions influence how professionals navigate strategic expectations and perceive their contribution to value creation.

To explore these questions, the study draws on qualitative insights from semi-structured interviews conducted with professionals working in engineering-driven environments. The interviews examine how professionals experience organisational pressures, resource constraints and evolving strategic expectations, as well as how they interpret their role within projectified organisational contexts. By focusing on the lived experiences of professionals, the study aims to contribute to a deeper understanding of the human mechanisms through which value is created and sustained in high-performing technical organisations.

3 METHODS

3.1 Research Design

This study adopts a qualitative research approach to explore how professionals in engineering-driven organisations interpret strategic expectations and adapt their professional practices within projectified work environments. Given the exploratory nature of the research and the focus on understanding professional interpretations and experiences, semi-structured interviews were selected as the primary data collection method. This approach enables in-depth insights into how professionals perceive organisational conditions, strategic expectations and the soft organisational factors shaping their contribution to value creation.

3.2 Data Collection

Data were collected through semi-structured interviews conducted in early 2026 in Zagreb, Croatia. The interviews explored professionals' experiences with projectified work environments, organisational pressures, communication practices, motivational factors and perceptions of their role in contributing to organisational value creation.

Each interview lasted approximately 20–30 minutes. During the interviews, detailed notes were taken manually. Immediately after each interview, the notes were systematically organised and expanded to ensure accurate representation of the participants' responses and key observations.

Participation in the study was voluntary, and participants were informed about the purpose of the research. Anonymity and confidentiality of responses were guaranteed, and no identifying information about individuals is disclosed in the analysis.

3.3 Sample

The study includes eight interviews with professionals working within an Engineering, Procurement and Construction (EPC) organisational environment. Although all participants were employed within the same organisation, they represented different professional roles and perspectives across the project lifecycle. All participants had extensive professional experience in international EPC project environments.

Participants included project managers, heads of technical support departments, design engineers involved in projects from the tendering phase to the as-built stage, and the head of the tendering department. This diversity of roles allowed the study to capture multiple perspectives on projectified work practices and organisational expectations within engineering-driven environments.

To ensure anonymity, interview participants were coded (P1–P8), and their roles and functional areas are presented in Table 1.

Table 1: Profile of Interview Participants

Participant	Role	Functional area
P1	Head of Technical Department	Engineering / EPC support
P2	Project Manager	Project delivery
P3	Project Manager	Project delivery
P4	Head of Technical Department	Engineering / EPC support
P5	Lead Engineer	Design / EPC support
P6	Lead Engineer	Design / EPC support
P7	Lead Engineer	Design / EPC support
P8	Head of Sales Department	Tendering / Sales

(Source: Authors' own work)

3.4 Data Analysis

The collected interview notes were analysed using thematic analysis. The analysis focused on identifying recurring patterns and themes related to professionals' experiences of projectified work environments, organisational pressures and the role of soft organisational factors in shaping their professional practices.

The analysis involved several iterative steps. First, the interview notes were reviewed to identify key statements and recurring topics across interviews. These initial observations were then grouped into broader thematic categories reflecting shared experiences as well as contrasting perspectives among participants. Particular attention was given to identifying patterns related to organisational pressures, resource constraints, communication dynamics, motivation and perceptions of professional contribution to value creation. The resulting thematic structure and the analytical focus of the interview questions are summarised in Table 2.

Table 2: Thematic Categories and Analytical Focus of Interview Questions

Theme	Example questions	Analytical focus
Strategy interpretation	Q1	How professionals understand and interpret organisational strategy
Professional competencies	Q2, Q8	Development of project management competencies
Organisational change	Q3	Perception of projectification and organisational transformation
Project complexity	Q4	Increasing workload and project pressure
Resource constraints	Q5, Q6	Adaptation mechanisms in resource-limited environments
Professional adaptation	Q7	Skills developed for coping with project environments
Project challenges	Q10	Operational pressures and project delivery challenges
Future competencies	Q11	Skills required in projectified environments
Management perspective	Q12, Q13	Organisational responses to project growth

(Source: Authors' own work)

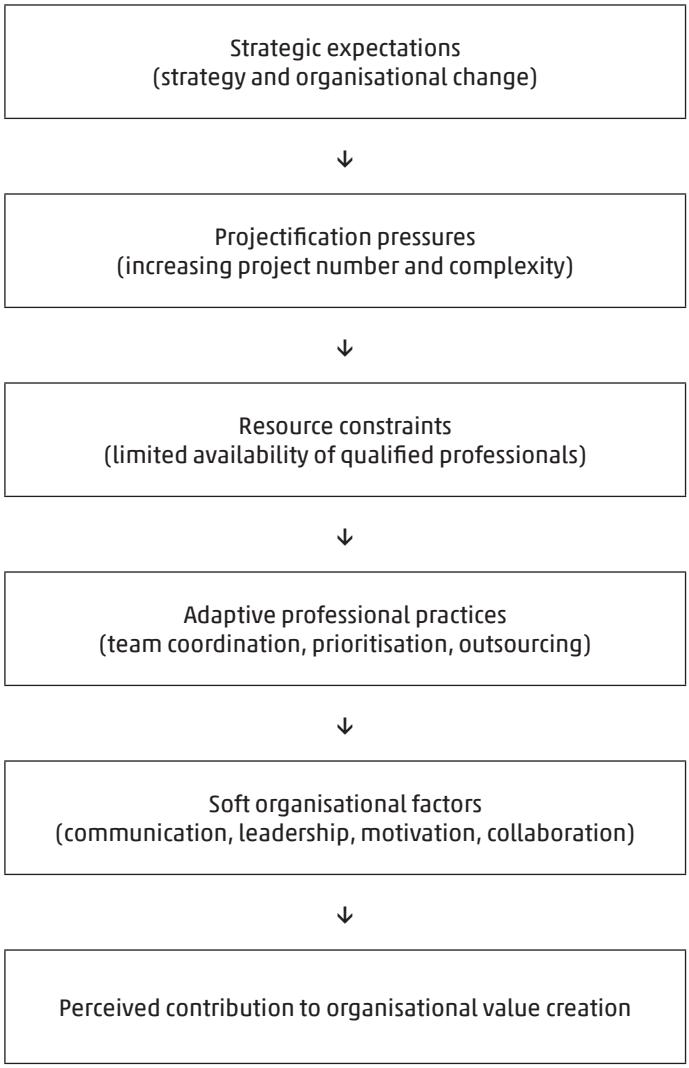
4 RESULTS

The thematic analysis of the interviews revealed several recurring patterns related to how professionals interpret strategic expectations, experience increasing project pressure, and adapt their professional practices within projectified work environments.

The analysis identified main thematic categories related to strategic expectations, projectification pressures, resource constraints, and adaptive professional practices. The relationships between these themes and their contribution to organisational value creation are illustrated in Figure 1.

The findings suggest a sequential relationship in which increasing strategic expectations and projectification pressures generate resource constraints, which in turn trigger adaptive professional practices. The effectiveness of these adaptations appears to be strongly influenced by soft organisational factors, ultimately shaping professionals' perceived contribution to organisational value creation.

Figure 1: Key themes emerging from the interview analysis



(Source: Authors' own elaboration based on interview analysis)

4.1 Interpretation of Strategy and Organisational Change

Interviews indicate that professionals generally demonstrate a good understanding of the overall strategic direction of the organisation. Across all interviews, respondents reported familiarity with the company's strategic objectives and recognised the importance of aligning project work with broader organisational goals.

However, a recurring pattern concerns the limited clarity of how strategic objectives are translated into operational project practices. Participants frequently emphasised that while strategy is communicated at a general organisational level, the mechanisms through which strategic priorities are operationalised within projects remain less clearly structured.

Several respondents also pointed to inconsistencies between organisational units in the interpretation and communication of strategic priorities, which occasionally creates uncertainty at the project team level. In addition, the interviews suggest that the level of understanding of organisational strategy tends to increase with professional experience and organisational tenure.

One participant described this situation as follows:

"I understand the strategy and the general objectives of the company, but the operational plan is not completely clear." (P1)

These findings indicate a perceived gap between strategic intent and operational implementation, particularly within project environments where coordination across organisational units is required.

4.2 Increasing Project Pressure and Complexity

A consistent pattern across the interviews concerns the perceived increase in the number, complexity, and pace of projects. All participants indicated that project workloads have intensified over time, particularly within engineering-driven environments operating in international markets.

Respondents highlighted that the increase in the number of projects is accompanied by higher technical complexity, stricter international standards, and more demanding administrative requirements. These developments require greater coordination across organisational units and impose additional demands on professionals involved in project delivery.

Participants also emphasised that the growing pace of projects significantly affects everyday professional activities. Work processes are perceived as becoming faster and more intensive, requiring professionals to simultaneously manage multiple responsibilities and deadlines.

One respondent summarised this development as follows:

"The number of projects is increasing. Their value, complexity and risks are also increasing." (P3)

In addition to the increasing workload, several respondents pointed to the growing role of administrative and procedural requirements associated with international project environments. These requirements often extend beyond purely technical work and require additional time and organisational coordination.

Overall, the findings suggest that project environments are becoming increasingly demanding, both in terms of technical complexity and operational intensity. This trend contributes to a perception of intensified project pressure among professionals working in EPC project environments.

4.3 Resource Constraints and Adaptive Practices

Another prominent theme emerging from the interviews concerns the availability of organisational resources required to support the increasing number and complexity of projects. Across all interviews, respondents highlighted the limited availability of qualified professionals within EPC project environments.

Participants emphasised that the shortage of experienced engineers and project professionals represents one of the main constraints affecting project delivery. The lack of specialised expertise complicates project planning and often requires teams to operate with limited human resources.

Several respondents also pointed to a broader structural challenge related to the attractiveness of EPC environments for younger professionals. Some participants noted that younger generations appear less interested in pursuing careers within technically demanding project environments, which further contributes to concerns about the long-term availability of qualified professionals.

As project demands frequently exceed formally planned capacities, teams adapt through a range of practical adjustments. These include redistributing personnel across projects, outsourcing specific technical tasks, reorganising internal responsibilities, and prioritising activities according to project urgency.

In some cases, respondents also reported the use of overtime work or the postponement of certain project activities in order to meet deadlines and contractual obligations. These responses illustrate the operational flexibility required in project-based environments where resource constraints are common.

One participant described the situation as follows:

"The lack of qualified professionals represents one of the main challenges." (P6)

Overall, the findings suggest that while project teams demonstrate a significant capacity for short-term adaptation, many of these responses remain reactive rather than strategically structured. This indicates a broader organisational challenge related to aligning project demands with available professional capacities.

4.4 Professional Skills and Soft Organisational Factors

The interviews also revealed the growing importance of interpersonal, organisational, and motivational factors in project work. While technical expertise remains the core professional foundation in engineering-driven organisations, respondents consistently emphasised that successful navigation of complex project environments requires a broader set of competencies.

Participants highlighted that communication skills, teamwork, and organisational capabilities are increasingly important in coordinating project activities across multiple stakeholders and organisational units. In addition to technical competence, professionals emphasised the need for structured work approaches, prioritisation skills, and the ability to manage multiple parallel tasks within demanding project environments.

Several respondents also pointed to the increasing importance of interpersonal competencies, particularly the ability to collaborate effectively within multidisciplinary teams and to manage communication across organisational boundaries.

One participant described this shift as follows:

"Communication skills and teamwork are becoming essential for working in complex project environments." (P2)

*Beyond operatio*nal competencies, participants also emphasised the role of motivation, supportive leadership, and a positive working environment in sustaining long-term project performance. Respondents noted that professionals are more willing to engage with demanding project tasks when they perceive their work as meaningful and when organisational communication supports a clear understanding of their contribution.

"When employees understand their contribution and the purpose of their work, they become more motivated and willing to take on new challenges." (P7)

Overall, the findings suggest that soft organisational factors, such as communication quality, leadership support, and motivational dynamics, play a significant role in enabling professionals to navigate the pressures of projectified work environments and sustain their contribution to organisational value creation.

4.5 Management Perspective

An additional insight emerged from the interview questions that invited participants to reflect on the situation from the perspective of organisational management. When asked how they would address the increasing number of projects and the pressure to generate greater value with the existing workforce, several respondents expressed uncertainty in formulating concrete managerial approaches.

This hesitation suggests that professionals primarily interpret project challenges from an operational perspective and may feel less confident when reflecting on strategic organisational decision-making.

However, when the discussion shifted toward broader organisational priorities such as motivation, quality, innovation, and profitability, participants offered more concrete suggestions. In particular, respondents emphasised the importance of clear communication, employee motivation, and a supportive working environment as key organisational conditions for sustaining performance in project environments.

One participant reflected this perspective by noting that:

"A stronger focus on fewer but higher-value projects, combined with investment in employee development and motivation, would be essential to address increasing project demands." (P1)

Participants frequently highlighted that improving communication between management and employees and strengthening organisational support structures could contribute to both employee engagement and long-term organisational resilience.

These responses suggest that while professionals may feel uncertain about strategic decision-making responsibilities, they clearly recognise the importance of organisational culture, communication, and motivation in enabling sustainable project performance.

5 DISCUSSION

5.1 Projectification and Changing Work Practices

The findings of this study suggest that professionals in engineering-driven organisations increasingly experience the effects of projectification in their everyday work. Respondents reported a growing number of projects, increasing technical complexity and intensified coordination requirements across organisational units. These developments indicate that project work is becoming more demanding, requiring professionals to manage multiple responsibilities while operating under tighter time and resource constraints.

These observations reflect broader trends described in the literature on projectification, where project-based modes of organising increasingly shape organisational coordination and everyday work practices (Midler 1995; Lundin et al. 2015; Jacobsson and Jałocha 2021). In projectified environments, projects become not only the dominant mechanism for delivering outputs but also a central organisational logic structuring how work is planned, coordinated and evaluated.

Importantly, the results suggest that projectification influences not only organisational structures but also the everyday practices and professional roles of individuals, reshaping how each professional understands and performs his or her own responsibilities. As projectification spreads across organisations, professionals increasingly combine technical expertise with coordination and communication responsibilities. Respondents described situations where project work extends beyond purely technical tasks and requires managing interactions across departments and project interfaces.

Such dynamics illustrate what previous research describes as the projectification of work and individuals, where project-based organising reshapes professional roles, responsibilities and expectations (Jacobsson and Jałocha 2021). Professionals in project-intensive environments must therefore navigate shifting organisational priorities while balancing technical tasks with broader coordination responsibilities.

Within the EPC context examined in this study, the effects of projectification are particularly visible through increasing project pressure and operational complexity. Respondents emphasised the growing number of projects as well as additional administrative and coordination requirements associated with international project environments.

As a result, professionals develop adaptive practices aimed at coping with these challenges. The interviews revealed that teams frequently respond to increasing project demands through task redistribution, outsourcing specialised activities and prioritising project responsibilities according to urgency in order to maintain project delivery despite organisational constraints.

Taken together, these findings suggest that projectification in engineering-driven organisations manifests not only through the increasing number of projects but also through changes in everyday work practices and professional roles. Professionals increasingly operate in environments characterised by overlapping project responsibilities, evolving coordination requirements and the need for continuous adaptation.

5.2 Projectification and Professional Identity

The findings of this study also suggest that projectified environments influence how professionals perceive their roles and responsibilities within engineering-driven organisations. Participants described situations in which project work requires them to simultaneously manage technical tasks, administrative requirements and organisational coordination across departments and project phases. As a result, professional responsibilities extend beyond traditional engineering tasks and increasingly include communication, coordination and organisational negotiation.

These dynamics reflect broader trends identified in research on projectified work environments, where project-based modes of organising reshape not only organisational structures but also the roles and identities of professionals (Jacobsson and Jałocha 2021). In such environments, professionals frequently navigate shifting responsibilities, multiple project interfaces and evolving organisational expectations.

This phenomenon has been described as the emergence of the "projectified self", where knowledge workers increasingly interpret their professional roles through the lens of project-based work and organisational flexibility (Kalff 2017). Within these contexts, professional identity is shaped not only by technical expertise but also by the ability to coordinate complex tasks, communicate across organisational boundaries and adapt to changing project demands.

The findings illustrate similar dynamics within EPC project environments. Respondents emphasised that effective participation in projects requires professionals to combine technical competence with organisational awareness, communication skills and the ability to coordinate activities across multiple stakeholders. These findings suggest that even professionals in non-managerial or mid-level roles require a broader understanding of project delivery within organisational and strategic contexts. In this sense, projectification not only restructures how work is organised but also influences how professionals understand their contribution within the organisation. Professionals increasingly operate as hybrid actors who combine technical expertise with coordination and communication responsibilities while navigating between engineering tasks, project management requirements and organisational expectations.

5.3 Resource Constraints and Adaptive Professional Practices

Another important finding emerging from the interviews concerns the relationship between increasing project pressure and the availability of organisational resources. Respondents consistently reported that the growing number and complexity of projects are often not matched by a corresponding increase in qualified professionals.

This pattern reflects broader dynamics observed in projectified organisations, where the increasing number of projects generates new coordination challenges and organisational pressures (Midler 1995; Lundin et al. 2015).

In response to these constraints, professionals frequently develop adaptive practices aimed at maintaining project delivery despite organisational limitations. Participants described redistributing responsibilities across project teams, outsourcing specialised tasks and reorganising internal priorities in order to address the most urgent project demands.

Such responses illustrate how professionals adapt their work practices within projectified organisational settings, where project-based modes of organising increasingly shape everyday work activities (Wagner and Radujković 2025). This raises an important question regarding whether available resources are utilised in an efficient and effective manner within projectified environments.

From this perspective, adaptive practices can be understood as micro-level responses to changing project demands, reflecting an emerging but not yet fully developed organisational capacity for dynamic adaptation.

5.4 Soft Organisational Factors and Value Creation

Another important insight emerging from the findings concerns the role of soft organisational factors in enabling professionals to cope with the pressures of projectified work environments. Respondents consistently emphasised the importance of communication, collaboration, leadership support and motivational dynamics as key conditions shaping professional performance in project settings.

While technical competence remains the foundation of work in engineering-driven organisations, the results suggest that effective project delivery increasingly depends on the quality of organisational interactions among project participants. In particular, respondents highlighted that communication, supportive leadership and a positive working environment significantly influence professionals' ability to coordinate tasks, manage project complexity and sustain motivation.

These observations suggest that value creation in project environments cannot be understood solely through traditional project performance indicators such as time, cost and scope. Instead, organisational and behavioural factors play an important role in enabling professionals to sustain project performance and contribute to broader organisational outcomes.

This interpretation aligns with recent developments in project management literature, which emphasise that project value emerges not only from technical outputs but also from organisational conditions that support collaboration and knowledge integration (Laursen and Svejvig 2016; Radujković et al. 2021; Zwikael 2024).

5.5 Motivational Perspective: Self-Determination Theory

From a motivational perspective, the findings can be interpreted through the lens of Self-Determination Theory (SDT), which suggests that individuals are more likely to sustain engagement when their needs for autonomy, competence and relatedness are supported within organisational environments (Deci et al. 2017).

The interviews indicate that professionals working in projectified environments are strongly influenced by organisational conditions that shape their perception of contribution, recognition and collaboration within project teams. Respondents emphasised that motivation increases when they understand the purpose of their work and when organisational communication connects their project tasks with broader organisational goals.

The findings also highlight the importance of communication, teamwork and leadership support in helping professionals cope with project pressure and complex coordination requirements. Such conditions contribute to the need for relatedness and support a sense of belonging within project teams.

At the same time, opportunities to apply technical expertise and manage complex project tasks appear to strengthen professionals' perception of competence. Together, these conditions suggest that projectified environments can support motivation when professionals experience autonomy in their work, recognition of their competence and meaningful collaboration with colleagues.

5.6 Managerial Implications

An additional insight emerging from the interviews concerns the limited confidence professionals expressed when reflecting on strategic organisational decisions. While respondents demonstrated strong awareness of operational project challenges, they appeared less certain when asked to propose managerial responses to increasing project pressure and organisational constraints.

This observation may indicate a perceived distance between operational project work and strategic decision-making within projectified organisations, where professionals focus primarily on project coordination and delivery while strategic decisions regarding project portfolios and resource allocation remain concentrated at higher managerial levels.

Such dynamics relate to broader discussions in project management literature on the relationship between project governance and project performance, where alignment between organisational strategy and project execution depends on effective governance structures and managerial coordination mechanisms (Müller et al. 2017; Müller et al. 2019).

At the same time, respondents emphasised the importance of communication, leadership support and employee motivation in sustaining project performance. From a managerial perspective, this suggests that organisational leadership plays a key role in creating environments that support professional engagement and enable project value realisation (Zwikael 2024).

5.7 Limitations

This study has several limitations. First, the empirical data were collected within a single engineering-driven organisation, which may limit the generalisability of the findings. Second, the study is based on a relatively small sample of interviews. However, the purpose of this exploratory research was not statistical generalisation but rather analytical insight into how professionals interpret projectified work environments.

5.8 Implications and Future Research

Future research could extend this study by examining multiple engineering-driven organisations across different national or industrial contexts. Comparative studies could provide deeper insights into how projectification influences professional practices and organisational dynamics across different organisational settings. Further research could also combine qualitative and quantitative approaches to explore the relationship between projectification, professional motivation and value creation in greater depth.

6 CONCLUSION

This study explored how professionals working in engineering-driven organisations undergoing strategic transformation interpret projectified work environments and the organisational factors that shape their contribution to value creation. The findings indicate that increasing projectification is experienced primarily through growing project pressure, rising technical complexity and intensified coordination requirements. These conditions require professionals to adapt their work practices by combining technical expertise with broader organisational and interpersonal competencies.

The results further suggest that resource constraints and increasing project workloads frequently lead to adaptive responses such as task redistribution, prioritisation and outsourcing. While such practices allow projects to continue progressing, they often represent reactive responses to structural organisational pressures rather than strategically coordinated solutions.

An important insight emerging from the study concerns the role of soft organisational factors in enabling professionals to cope with the demands of projectified environments. Communication quality, leadership support, collaboration and motivational dynamics appear to play an important role in sustaining professional engagement and facilitating effective coordination within project teams. These findings support broader perspectives in project management literature which emphasise that value creation in projects depends not only on technical performance but also on organisational and behavioural conditions that support collaboration and knowledge integration.

From a practical perspective, the results suggest that organisations operating in highly projectified environments should pay greater attention to the organisational conditions that shape professional motivation, communication and collaboration within project teams. Strengthening these soft organisational factors may contribute to more sustainable project performance and improved organisational value creation.

Future research could extend this study by examining projectified environments across multiple organisations and industries in order to better understand how projectification influences professional practices and organisational value creation in different contexts. Further studies could also explore the relationship between projectification, professional motivation and project performance using combined qualitative and quantitative research approaches.

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STRATEGIC COMMUNICATION MANAGEMENT

1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

EMPOWERING THE VOICES OF CHILDREN WITH SPEECH AND LANGUAGE DISORDERS IN EDUCATIONAL AND SOCIAL SPACES

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ABSTRACT

Children with speech and language disorders may experience significant barriers to participation in educational and social environments. Although speech and language difficulties are often approached primarily through therapeutic intervention, effective inclusion also depends on the communicative environments in which children learn, interact, and participate. This review article examines the role of strategic communication management as a framework for supporting the inclusion and empowerment of children with speech and language disorders in educational and social contexts.

The article explores the role of strategic communication management in the inclusion of children with special needs, particularly those with speech and language disorders, into social and educational processes. The starting point is the idea that communication is not just the transfer of information, but a strategic tool for empowerment and inclusion. The article presents models and approaches that enable the creation of environments where children's communication needs are recognized, understood, and supported, and emphasizes the importance of collaboration among professionals in the fields of speech therapy, communication management, and education. The aim is to show how strategic communication can contribute to the development of an empathetic and effective communication culture that promotes equal inclusion of children with speech and language disorders in the broader social discourse. The literature indicates that communication should be understood not only as the transmission of information but also as a mechanism through which participation, agency, relationships, and social belonging are enabled.

Keywords: *strategic communication, inclusive communication, speech and language disorders, children's voice, social inclusion*

1 INTRODUCTION

Inclusive education and social participation of children with special needs have become central goals of contemporary educational and social policies. Among various challenges faced by children with special needs, speech and language disorders present a particularly significant barrier to participation, as communication is a foundational mechanism through which individuals express needs, build relationships, and engage in learning processes. Traditional approaches often treat communication difficulties primarily as individual deficits to be corrected through therapeutic intervention. While speech therapy plays a crucial role, such a perspective may overlook the broader communicative environment in which the child operates. This article argues that inclusion cannot be achieved solely by improving a child's communicative abilities; it also requires strategic management of communication within educational institutions and social contexts.

A deficit-oriented perspective may locate the problem primarily within the child and therefore focus predominantly on improving the child's communication skills. Such an approach may also overlook the broader responsibilities of educational systems in creating conditions that enable participation and inclusion (Hart 1994). Hart (1994) emphasises the importance of reconsidering responsibility and entitlement within educational provision, while Daniels (2000) highlights the need to move beyond purely rhetorical approaches to special education and to consider how educational structures and practices shape the experiences of children with special educational needs. These perspectives are particularly relevant when considering children whose participation may be constrained by institutional expectations and practices. Speech and language therapy is undoubtedly important, but an exclusive focus on the individual can overlook the role of the environment.

Speech and language disorders encompass a broad range of difficulties affecting speech production, language comprehension and expression, fluency, vocabulary, grammar, social communication, and pragmatic language. These difficulties can influence children's experiences in classrooms and peer groups and may affect their opportunities to demonstrate knowledge and participate in social interaction. Existing research has also drawn attention to the longer-term behavioural, emotional, and social consequences associated with childhood language difficulties (Lindsay and Dockrell 2012; St Clair et al. 2011). A deficit-oriented perspective may locate the problem primarily within the child and therefore focus predominantly on improving the child's communication skills. Speech and language therapy is undoubtedly important, but an exclusive focus on the individual can overlook the role of the environment. Communication is relational: the success of an interaction depends not only on what a child can communicate but also on whether other people are willing and able to listen, adapt their communication, provide sufficient time, and recognise alternative forms of expression.

Research concerning children with complex communication needs similarly demonstrates the importance of moving beyond verbal communication as the sole indicator of participation. Lewis-Dagnell et al. (2023), for example, found in their systematic review that multimodal, flexible, and individualised approaches can enable children with complex needs to express their views about educational experiences. Their review also emphasised the importance of allowing sufficient time and using a range of methods rather than relying on standardised approaches to communication.

This distinction is particularly important when considering children's right to express their views. Lundy's (2007) conceptualisation of children's participation emphasises that having a voice involves more than simply being given an opportunity to speak. Children require an appropriate space in which to express themselves, opportunities to communicate their views, an audience that listens, and the possibility that their views will influence decisions. For children whose communication does not conform to conventional expectations, each of these dimensions may require deliberate adaptation.

Against this background, this article considers **strategic communication management** as a conceptual framework for inclusive practice. Strategic communication is understood here as the intentional coordination of communication processes, relationships, messages, practices, and institutional conditions in pursuit of defined organisational and social goals.

The central argument of this article is that inclusion cannot depend exclusively on improving the communicative competence of individual children. It also requires educational and social environments to become more communicatively accessible, responsive, and flexible.

The purpose of this review article is therefore to examine how strategic communication can contribute to the empowerment and inclusion of children with speech and language disorders and to identify communication principles that can support more inclusive educational and social environments.

The article is guided by three questions:

1. How can communication be conceptualised as a mechanism of inclusion and participation for children with speech and language disorders?
2. Which communication approaches and principles can support children's participation in educational and social environments?
3. What role can interdisciplinary collaboration and institutional communication practices play in developing sustainable inclusive communication environments?

1.1 Communication as a Strategic Tool for Inclusion

Communication is commonly understood as the exchange of information between a sender and a receiver. However, in inclusive contexts, communication functions as a strategic process that shapes power relations, access to participation, and social belonging. Strategic communication management involves the intentional planning, implementation, and evaluation of communication practices to achieve defined social and organizational goals. In the context of inclusion, these goals include: ensuring equal access to communication, recognizing diverse communication styles and needs, reducing communicative barriers within educational and social systems.

For children with speech and language disorders, ineffective communication strategies can lead to marginalization, misunderstanding, and reduced self-esteem. Conversely, strategically designed communication environments can empower children by validating their modes of expression and facilitating meaningful interaction. Speech and language disorders encompass a wide range of difficulties, including articulation disorders, language delays, fluency disorders, and pragmatic communication challenges. These difficulties can affect not only academic performance but also peer relationships and emotional development. In educational settings, communication challenges may result in: limited classroom participation, misinterpretation of cognitive abilities, social isolation. From a strategic communication perspective, these outcomes are not solely the result of the child's impairment but also of the communicative norms and expectations embedded within institutions. When educational systems rely on narrow definitions of "appropriate" communication, children who deviate from these norms are at risk of exclusion.

2 METHODOLOGY

This article is designed as a review article based on a narrative synthesis of relevant literature. It does not constitute a systematic literature review and does not claim to follow a systematic-review protocol such as PRISMA.The purpose of the review is conceptual rather than exhaustive. Relevant literature concerning speech and language difficulties, inclusive education, children's participation and voice, communication practices, interdisciplinary collaboration, and educational inclusion is brought together and interpreted in relation to the central concept of strategic communication management.

The literature considered includes theoretical works, empirical studies, professional and policy-oriented publications, and previous review studies relevant to the topic. Particular attention is given to literature addressing communication barriers, the perspectives of children with communication needs, collaboration between education and speech and language therapy, and the development of inclusive communication environments.

The narrative approach is appropriate for the purpose of this article because the literature concerning communication and inclusion is interdisciplinary and encompasses different theoretical traditions, research designs, and professional perspectives. The objective is not to calculate an overall effect size or to claim exhaustive identification of all available studies, but to integrate existing knowledge into a conceptual framework that can inform educational and social practice.

The review is consequently organised around several interconnected themes: communication and participation, speech and language disorders, strategic communication, participatory and multimodal communication, ecological approaches, empathy and responsiveness, interdisciplinary collaboration, and institutional communication culture.

3 COMMUNICATION, PARTICIPATION AND INCLUSION

Communication is fundamental to participation. Through communication, children express needs and preferences, establish relationships, demonstrate knowledge, negotiate social situations, and contribute to decisions that affect them.

For children with speech and language disorders, however, participation may be constrained when institutions define successful communication according to narrow linguistic or behavioural norms. A child who requires additional processing time, visual support, augmentative and alternative communication, gestures, symbols, writing, technology, or other forms of expression may be perceived as less competent if the surrounding environment is not prepared to recognise these forms of communication.

This problem illustrates an important distinction between **communication difficulty** and **communication accessibility**. A child's communication needs may be real, but the degree to which those needs become barriers to participation depends partly on the environment.

The ecological perspective developed by Bronfenbrenner (1979) provides a useful theoretical basis for understanding this relationship. Children's development occurs within interconnected environments, including family, school, peer groups, professional services, and broader social institutions. Communication therefore cannot be understood independently from the relationships and systems in which it takes place.

From this perspective, inclusive communication requires attention to the whole communicative environment. A teacher's ability to adapt classroom communication, peers' willingness to listen, parents' knowledge of the child's communication preferences, and speech and language therapists' collaboration with educational staff may all influence participation.

The literature on children's voice further challenges the assumption that verbal fluency should determine whether a child's perspective is heard. Lewis-Dagnell et al. (2023) demonstrate that children with complex needs can participate in expressing their views when researchers and professionals use flexible and multimodal methods. Their findings are particularly relevant to educational inclusion because they demonstrate that communication should be adapted to the individual child rather than requiring the child to conform to a single communication standard.

4 CHILDREN WITH SPEECH AND LANGUAGE DISORDERS IN EDUCATIONAL AND SOCIAL CONTEXTS

Speech and language disorders represent a diverse group of communication difficulties. They may affect speech production, language development, comprehension, expression, fluency, vocabulary, grammar, or pragmatic and social communication.

The terminology used in this field has changed considerably over time. Bishop et al. (2015) highlighted the complexity of defining language impairment and the importance of using terminology that reflects the diversity of children's communication profiles.

Educational environments can present particular challenges. Classroom communication frequently requires children to understand complex instructions, respond rapidly to questions, participate in group discussion, explain reasoning, engage in peer interaction, and demonstrate knowledge verbally. A child with communication difficulties may therefore know the answer to a question but have difficulty expressing it in the expected form or within the expected time.

Teachers may consequently underestimate a child's cognitive or academic abilities when communication difficulties are interpreted as a lack of understanding.

5 STRATEGIC COMMUNICATION AS A FRAMEWORK FOR INCLUSION

Strategic communication is generally associated with the intentional planning and coordination of communication in order to achieve organisational or social objectives. In an inclusive educational context, however, the concept can be extended beyond institutional messaging.

Strategic communication can encompass:

- the planning of communication processes;

- adaptation of communication to individual needs;
- coordination between professionals;
- development of shared communication goals;
- institutional communication policies;
- communication-related professional development;
- mechanisms for feedback;
- opportunities for children to express their views;
- and evaluation of whether communication practices actually support participation.

This broader understanding is particularly relevant to children with speech and language disorders because communication barriers frequently arise at the intersection between individual needs and institutional expectations. An inclusive strategic communication framework therefore shifts the question from: *How can the child communicate more effectively?* towards a broader question: *How can the environment communicate in ways that enable this child to participate?* Speech and language therapists may identify specific communication needs and strategies, while teachers can integrate those strategies into everyday classroom practice. Psychologists and other professionals may contribute knowledge about emotional and social development, while parents and carers can provide detailed knowledge about the child's preferences, strengths, and communication patterns.

6 MODELS OF STRATEGIC COMMUNICATION FOR INCLUSIVE ENVIRONMENTS

6.1 Participatory Communication Model

A participatory approach places the child at the centre of communication and recognises the child as an active participant rather than a passive recipient of intervention. Participation may occur through speech, gestures, facial expressions, visual supports, drawing, writing, symbols, communication boards, digital technologies, or augmentative and alternative communication systems. The important principle is that the communication modality should not determine the legitimacy of the child's contribution. Research on children with complex communication needs strongly supports the use of flexible and multimodal approaches. Lewis-Dagnell et al. (2023), for example, found that creative and individualised approaches can facilitate children's voices and participation and argued against relying exclusively on conventional verbal methods.

In educational practice, a participatory approach may involve giving children different ways to answer questions, express preferences, participate in classroom activities, provide feedback, and contribute to decisions. Strategic communication management ensures that these approaches become part of ordinary practice rather than being treated as exceptional accommodations.

6.2 Ecological Communication Model

The ecological model views communication as embedded within a network of relationships and environments.

The child's communicative experience is influenced by:

- family;
- teachers;
- peers;
- speech and language therapists;
- psychologists;
- support staff;
- educational leadership;
- health and social services;
- and broader institutional and social structures.

From this perspective, communication strategies should not be developed in isolation.

For example, a communication strategy developed by a speech and language therapist may have limited impact if classroom staff are unfamiliar with it or if it is used only during therapy sessions. Conversely, when the same strategy is integrated into classroom interaction and supported by peers and family members, opportunities for generalisation increase.

The ecological model therefore supports the development of **communication continuity** across environments.

6.3 Empathetic Communication Model

Empathetic communication places the child's communicative intention at the centre of interaction.

In practice, this means that professionals should avoid evaluating communication solely according to linguistic accuracy. They should also consider what the child is attempting to communicate, how the child prefers to communicate, what contextual factors influence communication, and what support may enable successful interaction.

Empathetic communication includes:

- active listening;
- allowing additional processing time;
- avoiding unnecessary correction;
- checking understanding;
- recognising non-verbal communication;
- responding to communicative attempts;
- respecting individual communication preferences;
- and demonstrating genuine interest in the child's perspective.

This approach can be particularly important for children whose speech is difficult for unfamiliar listeners to understand or whose communication is slower than expected.

Empathy therefore becomes not merely an interpersonal quality but a **strategic communication competence**.

7 DEVELOPING AN INCLUSIVE COMMUNICATION CULTURE

Individual communication strategies are important, but sustainable inclusion requires institutional change.

An inclusive communication culture is characterised by:

- respect for communicative diversity;
- openness to different communication modalities;
- flexibility in classroom interaction;
- recognition of children's agency;
- staff awareness of communication needs;
- interdisciplinary collaboration;
- and institutional commitment to participation.

Strategic communication management can contribute to such a culture by embedding inclusive communication principles into institutional policies and professional development.

For example, schools can develop communication guidelines that address:

- how staff should respond to different communication modalities;
- how additional processing time should be provided;
- how children can participate in decision-making;
- how communication preferences can be documented and shared;
- how staff should collaborate with speech and language therapists;
- and how children and families can provide feedback on communication practices.

Inclusive communication should therefore be embedded in institutional learning rather than treated as the responsibility of one specialist.

8 CHILDREN'S VOICE, AGENCY AND THE RIGHT TO PARTICIPATE

The concept of children's voice is central to the argument of this article.

Children with speech and language disorders may be particularly vulnerable to having their views overlooked because their communication can be misinterpreted as lack of competence, lack of understanding, or lack of interest. This creates a significant conceptual problem: communication difficulty must not be equated with absence of opinion. The work of Lundy (2007) is particularly useful because it conceptualises participation through four interconnected dimensions: space, voice, audience, and influence. For children with communication needs, each dimension may require adaptation.

Children need:

- a safe and appropriate space in which to express themselves;
- communication methods that correspond to their abilities and preferences;
- adults and peers who are prepared to listen;
- and evidence that their views are taken seriously and can influence decisions.
- This insight has direct implications for educational communication.
- The goal should not merely be to give a child an opportunity to communicate. The goal should be to create conditions in which communication **matters**.

9 SYNTHESIS AND DISCUSSION

The literature reviewed in this article suggests that communication should be understood as both an interpersonal process and an institutional responsibility. Three interconnected principles emerge from the literature. (1) **First, inclusion requires communicative flexibility.** Children do not communicate in identical ways. A communication environment that privileges rapid verbal responses may unintentionally disadvantage children whose communication requires additional time, visual support, alternative modalities, or technological assistance. Consequently, inclusive communication requires flexibility in how information is presented, how responses are accepted, and how children's views are elicited. (2) **Second, communication is relational and ecological.** Communication difficulties cannot be understood exclusively within the child. The surrounding environment influences whether a communication difference becomes a significant barrier to participation. This supports the application of ecological thinking to communication management. The quality and consistency of communication across teachers, therapists, families, peers, and institutions can influence the child's opportunities for participation. (3) **Third, inclusion requires institutional coordination.** Individual professionals may use highly effective communication strategies, but these strategies may have limited impact if they are not integrated into broader institutional practice. Strategic communication management can address this gap by providing a framework for coordinating communication goals, responsibilities, training, professional collaboration, and feedback.

The synthesis therefore suggests that strategic communication should not be viewed simply as a collection of techniques. It is better understood as an **organisational and relational framework for creating conditions in which diverse forms of communication are recognised and valued**. This perspective also changes the meaning of empowerment. Empowerment is not achieved merely when a child acquires greater communication competence. It also occurs when other people recognise the child's communication as meaningful, provide opportunities for participation, and respond to the child's contributions.

10 CONCLUSION

This review article has examined strategic communication as a conceptual framework for supporting the inclusion of children with speech and language disorders in educational and social environments. The central argument is that communication difficulties should not be understood exclusively as individual deficits requiring correction. Although speech and language therapy remains an important component of support, meaningful inclusion also depends on the communicative environment surrounding the child. Empowering the voices of children with speech and language

disorders therefore requires more than providing opportunities to speak. It requires creating spaces in which diverse forms of communication are recognised, audiences are prepared to listen, and children's contributions have the potential to influence educational and social life.

Strategic communication management can contribute to this transformation by positioning communication as a shared institutional responsibility and as a fundamental condition for participation, belonging, agency, and social inclusion. Participatory, ecological, and empathetic approaches offer complementary perspectives for developing inclusive communication practices. Participatory communication recognises children as active contributors; ecological communication emphasises the interconnected nature of family, educational, therapeutic, and social environments; and empathetic communication focuses attention on communicative intention, responsiveness, and respect.

The literature further indicates that interdisciplinary collaboration is essential for translating communication strategies across contexts. However, collaboration and inclusive practices may remain inconsistent when they depend solely on individual professionals. Strategic communication management can help address this challenge by connecting individual communication practices with institutional policies, professional development, shared goals, and mechanisms for feedback.

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1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

MONEY THROUGH CHILDREN'S EYES: THE ROLE OF FAMILY, SOCIETY, AND SCREENS IN THE DEVELOPMENT OF FINANCIAL LITERACY

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ABSTRACT

The understanding of money in children and adolescents is formed as early as the initial developmental stages and represents an important foundation for later financial behavior. Despite the growing interest in financial literacy, it remains relatively under-researched how children and adolescents themselves interpret money, its sources, and its use, and how these meanings change within the modern, digitized context. This research addresses the question of how children and adolescents, aged 6 to 15, understand money, its sources, and responsible use, and how these interpretations differ according to the developmental period and exposure to family and digital socialization influences.

The study is based on a qualitative research design and methodological triangulation. Data were collected through semi-structured interviews and the ‚draw-and-explain' method, which allows for an insight into the implicit and symbolic dimensions of economic thinking, particularly in younger children. The research included 20 participants, divided into two age groups: middle childhood (6–10 years) and early adolescence (11–15 years). The data were analyzed using thematic analysis of verbal responses and semantic-symbolic analysis of visual representations.

The results indicate distinct developmental differences in the understanding of money. Younger children perceive money primarily as a concrete object and a means for satisfying basic needs, often personalizing its sources. Adolescents develop a more abstract and reflective understanding of money, which includes concepts of saving, responsibility, planning, and digital forms of payment. In both age groups, moral and normative judgments regarding responsible money management are strongly present, confirming the significant role of the family in the process of financial socialization. Digital media appear primarily as a source of economic concepts, often without a direct experiential basis. This research contributes to the understanding of children and adolescents as active interpreters of economic concepts and emphasizes the importance of developmentally appropriate and critical financial education.

Keywords: *developmental financial literacy, financial socialization, digital financial socialization, money conceptualization, qualitative child research*

1 INTRODUCTION

The understanding of money in children and adolescents does not develop spontaneously but is the result of a complex interaction between cognitive development, socialization processes, and the broader cultural-economic context. Within this framework, money does not represent merely a technical medium of exchange but functions as a symbolically, normatively, and morally saturated concept linked to notions of work, value, justice, and social hierarchy. International empirical research consistently shows that fundamental economic concepts are formed as early as early childhood, with their complexity and level of abstraction changing significantly throughout developmental periods (Furnham and Argyle 1998; Webley and Nyhus 2006).

Classic developmental research, based on Piaget's theory of cognitive development, indicates that children in the pre-operational and concrete-operational stages understand money primarily on a functional and experiential level. In contrast, adolescents in the formal-operational stage gradually develop the ability to understand abstract and systemic economic processes, such as saving, debt, interest, and the institutional role of banks (Piaget 1970; Berti and Bombi 1988). Building on these theoretical foundations, Furnham and Argyle (1998) developed one of the most influential models of economic socialization, linking cognitive developmental stages with the understanding of economic concepts. Numerous subsequent empirical studies confirm a gradual shift from personalized explanations of the origin of money (parents, physical labor) to abstract and institutional explanations (banks, companies, financial systems) (Furnham and Argyle 1998; Webley et al. 2001).

Contemporary research emphasizes that the development of economic understanding is not merely an individual cognitive process but a socially situated process of financial socialization. Children and adolescents act as active interpreters in this process, adopting meanings, values, and norms related to money through everyday interactions (Gudmunson and Danes 2011). Financial socialization can thus be understood as a communication process in which money-related meanings and norms are transmitted through interpersonal and media-mediated communication. Meta-analytical and longitudinal studies confirm the statistically significant influence of parents on the formation of young people's financial attitudes and behaviors, whereby parents convey not only information but also implicit moral judgments about responsible and irresponsible money management (Clarke et al. 2005; Shim et al. 2010).

In the last decade, the research focus of financial socialization has increasingly shifted toward the impact of digitalization and cashless payment environments on the development of economic understanding. Empirical studies consistently show that non-material forms of payment—particularly card and mobile payments—reduce the perceived psychological burden of spending, which affects the perception of value and control over expenditures (Prelec and Simester 2001; Soman 2003; Raghubir and Srivastava 2008). In adolescents, this effect is often associated with greater impulsivity and a weaker perception of long-term financial consequences (Goedde-Menke et al. 2017).

Recent research on financial socialization emphasizes that the digital environment does not function merely as a technical means of payment but as an important socialization space. Meanings are mediated through applications, web platforms, and social networks (Gudmunson and Danes 2011; Shim et al. 2015). Studies indicate that adolescents often develop operational competence in using digital payment tools faster than a reflected understanding of financial risks, creating a gap between technical proficiency and financial literacy (Koskelainen et al. 2023). A particular challenge is the rise of commercial and entertainment digital content, where consumption, microtransactions, and financial risk are presented as part of everyday entertainment, further blurring the line between economic decision-making and play (Nairn and Fine 2008; Livingstone and Helsper 2010).

2 PURPOSE AND GOALS OF THE RESEARCH

2.1 Purpose of the research

The purpose of this research is to examine how children and adolescents across different developmental stages understand money, its sources, and its social function, and how these meanings are expressed in verbal and visual representations. The research is grounded in developmental-psychological and sociological theories of economic socialization and utilizes the developmental model of

Furnham and Argyle (1998) as an analytical framework for comparing two age groups: children in middle childhood (ages 6–10) and adolescents in early adolescence (ages 11–15).

The study does not merely assess how much a child knows about money but explores how they experience it, how they represent it symbolically, and what values they attribute to it. By employing methodological triangulation—using semi-structured interviews and the analysis of children's drawings—the research goes beyond the measurement of declarative knowledge to provide insight into the semantic structures that shape the economic thinking of young people in a modern, digitized context.

2.2 Goals of the research

The specific goals of the research are as follows:

- To identify and describe the fundamental models through which children and adolescents make sense of money, its sources, and its use in everyday life.
- To analyze developmental differences in the level of conceptual complexity between the younger and older age groups, focusing on the transition from concrete to abstract understanding of economic processes.
- To examine the moral and normative dimensions of understanding money, particularly perceptions of responsible behavior, saving, and spending.
- To evaluate the role of key socialization agents in shaping economic interpretations at both verbal and visual levels.

2.3 Research questions

Based on the defined purpose and goals, the research addresses the following research questions:

RQ1: How do children and adolescents define money, and which sources of money do they perceive as the most important?

RQ2: What moral and normative judgments about handling money do participants express, and how do these judgments differ according to the age group?

RQ3: How are the influences of the family and the digital media environment reflected in the verbal explanations and visual representations of money?

3 METHODOLOGY

The research is designed as a qualitative empirical pilot study aimed at an in-depth exploration of the subjective meanings that children and adolescents attribute to money. An interpretive research approach was selected, which is suitable for studying the symbolic, normative, and developmentally conditioned aspects of economic understanding. The methodological framework is based on methodological triangulation, combining semi-structured interviews and the analysis of children's drawings to determine whether the results are consistent across both methods.

3.1 Research sample

The research was conducted in Slovenia on a convenience sample of N = 20 participants, selected using the snowball technique. The sample was divided into two age groups reflecting key transitions in cognitive development: Children in middle childhood (ages 6–10; n = 10): Participants in this group are in the concrete-operational stage of thinking, characterized by the understanding of concrete information and limited capacity for abstraction (Piaget 1970; Santrock 2021). Adolescents in early adolescence (ages 11–15; n = 10): This group is characterized by the gradual development of formal-operational thinking and an increased ability to understand abstract social and economic systems (Piaget 1970; Steinberg 2014). The sample is non-representative and is intended for testing the research design and generating initial analytical insights.

3.2 Ethical aspects and data collection

The research was carried out in accordance with the ethical principles of social science research. Participation was voluntary, and the purpose of the study was presented in advance to all participants

and their parents or guardians. Anonymity was ensured through the use of pseudonyms, and the collected data were treated confidentially and used exclusively for research purposes. Data were collected between December 2025 and January 2026 in the home environment of the participants (Municipality of Hajdina).

Data collection took place in two consecutive phases:

Phase 1: Visual representation (Drawing): Participants received a uniform prompt: „Draw what money means to you, where people get it, and what they do with it." Drawing was used as a projective technique that allows children to express symbolic meanings that are often difficult to verbalize, especially for younger participants.

Phase 2: Semi-structured interview: The drawing was followed by a semi-structured interview adapted to the developmental level of the participants. For younger children, questions focused on concrete experiences, while for adolescents, they included more abstract aspects. The interviews were audio-recorded and transcribed verbatim.

3.3 Data analysis

The data analysis proceeded in several steps and included:

- Thematic analysis of verbal data: Interview transcripts were analyzed using open coding, identifying recurring themes and patterns in explanations of money, its sources, and moral judgments.
- Semantic-symbolic analysis of visual data: Children's drawings were analyzed for the presence of key symbols, actors, and compositional emphases.

The final interpretation is based on the integration of both data sources, with the developmental model of Furnham and Argyle serving as the analytical and interpretive framework.

4 RESULTS

The qualitative analysis of the interviews and drawings revealed four key thematic categories that define the conceptualization of money in children and adolescents: (1) Concept of money, (2) Sources of money, (3) Moral judgment, and (4) Forms of money.

4.1 Analysis of key thematic categories

Table 1 shows the coding frame with categories, codes, and representative statements of the participants.

Table 1: Coding frame for the analysis of economic understanding

Category	Code	Representative Statements
1. Concept of money	physical object	„It's coins and paper cash." (LP, 9)
	medium of exchange	„Something you use to buy things, like food or toys." (EL, 10)
	abstract value	„Money signifies a value and a worth, allowing you to buy things in order to survive." (BZ, 14)
2. Sources of money	salary	„Parents get it because they go to work." (TG, 15)
	gifts/family	„I get it from my parents and grandma for my birthday or from the tooth fairy." (KM, 7)
	institutional sources	„It comes from the bank, but you have to earn it first." (ZZ, 14)
3. Moral judgment	saving	„It's good to save, so you have it later for something big." (TŽ, 14)
	responsibility	„You shouldn't waste money on stupid things; you have to be responsible." (TT, 9)
	social inequality	„Some people manage money well and invest it, while others waste it on foolish things." (BZ, 14)
4. Forms of money	cards/apps	„I can pay with my phone or a card." (LP, 9)
	intangibility	„Money can also be in the form of cryptocurrencies or in gold." (RZ, 11)

(Source: Author's own visualization)

Across all age groups, money is primarily understood as a functional means for satisfying basic life needs. Children most frequently define money as something used to purchase food, drinks, clothing, and other essential goods. This understanding is distinctly concrete and experiential, especially among younger participants, who associate money with immediate daily activities, such as visiting a store or using an ATM. In adolescents, this understanding expands in a more abstract direction; money emerges as a medium that possesses value, requires responsible management, and enables long-term planning, including saving, investing, and budget allocation.

The sources of money described in the responses are multifaceted but clearly hierarchically structured. Labor and employment are recognized as the fundamental source of money, either directly or indirectly through parents. Younger children often mention the bank or an ATM as the place where money is „received," indicating a developmentally limited understanding of economic processes and institutional functions. Among older participants, an understanding emerges that includes concepts of salary, investment, and even entrepreneurship. Concurrently, gifts—primarily for birthdays and holidays—represent an important source of money, reflecting the strong role of family and kinship relationships in the process of financial socialization.

In the participants' responses, spending is divided into essential and non-essential. Basic life needs are present in almost all answers, while expenditures for toys, sweets, technology, or leisure are often labeled as less necessary or as items purchased less frequently. Interestingly, children do not only describe their own spending practices but also evaluate them. A clear normative dimension appears here, as children associate good money management with saving, deliberate shopping, and avoiding impulsive spending, while poor management is linked to wasting money on „nonsense" or things they do not need.

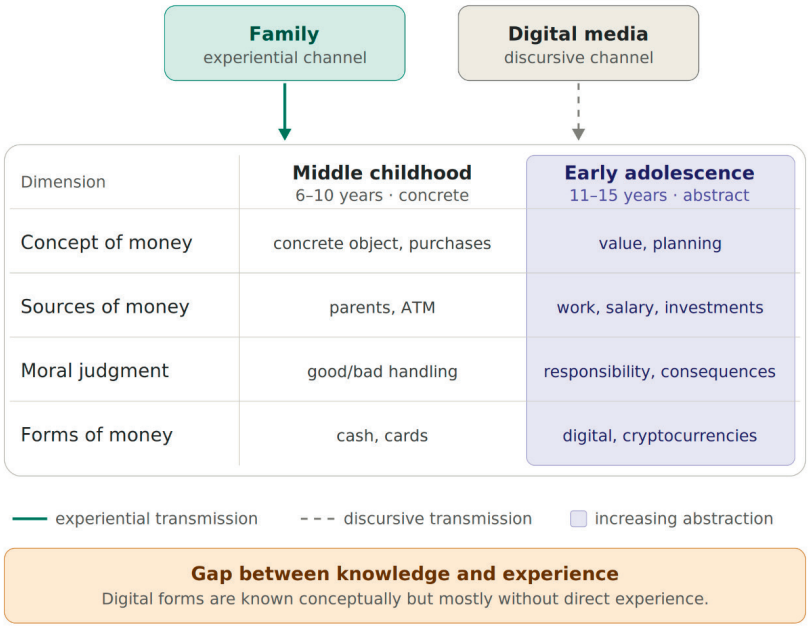
The moral discourse is particularly pronounced and goes beyond a mere description of behavior. Children often use value-laden language and reflexively position themselves within their own examples of good or bad financial management. This normative component is present across all age groups; however, the complexity of argumentation increases with age. Older participants more frequently mention responsibility, long-term consequences, and the social significance of money.

The forms of money identified in the responses are diverse. Cash and bank cards are universally recognized, while among older children and adolescents, digital forms of payment—such as mobile applications, electronic banking, and cryptocurrencies—also appear. Although these forms are frequently mentioned, it is not always clear whether this stems from actual experience or merely from knowledge acquired through the media and social environment.

4.2 Developmental differences in visual and verbal representations

The analysis of the drawings confirms the developmental shift from concrete to abstract representation. Younger children (6–10 years) predominantly drew physical coins, banknotes, and stores. Their visual representations are colorful and focused on immediate consumption. In contrast, adolescents (11–15 years) often included symbols of banks, credit cards, and digital devices (smartphones) in their drawings, reflecting a more complex understanding of the financial ecosystem. Figure 1 integrates these verbal and visual categories into a conceptual model, showing the developmental shift from concrete to abstract understanding, the two socialization channels, and the gap between conceptual knowledge and direct experience.

Figure 1: Conceptual model of children's and adolescents' understanding of money.



(Source: Author's own visualization)

5 DISCUSSION

The results of this study confirm that the conceptualization of money in children and adolescents is a dynamic process that reflects both cognitive developmental stages and the influences of the socialization environment. The findings are consistent with Piaget's (1970) theory and the developmental model of Furnham and Argyle (1998), as a clear transition from concrete-functional to abstract-systemic understanding of money was observed between the two age groups.

The participants in the middle childhood group (ages 6–10) perceive money primarily as a physical object and a direct medium for satisfying immediate needs. Their understanding of the origins of money is often personalized and limited to the domestic sphere or visible institutions (the bank as a „provider"), which is typical for the concrete-operational stage (Berti and Bombi 1988). In contrast, adolescents (ages 11–15) demonstrate a reflected understanding of the economic system, including concepts of saving, responsibility, and the long-term consequences of financial decisions. These findings support the claims of Webley and Nyhus (2006) regarding the gradual internalization of economic norms.

A key finding of the research is the presence of a strong moral and normative discourse across all age groups. Children do not merely describe economic categories but actively evaluate them through the lens of responsibility and „good" management. This confirms that the family remains a primary agent of financial socialization, conveying not only information but also moral values (Shim et al. 2010; Gudmunson and Danes 2011).

The digital environment appears as an increasingly influential factor in socialization. While younger children still associate money with physical form, adolescents are already integrating digital payments and intangible forms of value into their mental models. However, as noted by Koskelainen et al. (2023), a gap remains between technical proficiency in using apps and a deeper understanding of financial risks. Exposure to commercial digital content (Nairn and Fine 2008) further complicates the perception of money, as transactions often occur within the context of entertainment.

It is also meaningful to situate these findings within the framework of strategic communication, since financial socialization operates at its core as a communication process: meanings, norms, and

values related to money are transmitted through distinguishable communication channels. Two such channels, each with a different communicative logic, emerged prominently in this study. The family operates as the primary, experientially grounded channel, in which messages about money are conveyed through everyday interaction, the modeling of behavior, and often implicit moral judgments; this channel transmits both concepts and direct experience. The digital and media environment, by contrast, acts as a secondary, discursive channel in which concepts (e.g., card payments, cryptocurrencies) circulate through applications, platforms, and social networks, yet typically without an experiential basis.

Within this framework, the child or adolescent is not a passive recipient of messages but an active interpreter who processes the mediated meanings and incorporates them into their own explanations and visual representations of money. Such an understanding is consistent with interpretive approaches to communication, which treat the recipient as a co-creator of meaning, and complements established models of financial socialization that emphasize primarily the role of the family as a source of information and normative frameworks (Shim et al. 2010; Gudmunson and Danes 2011).

From a communication perspective, the identified gap between conceptual knowledge and experience can also be reinterpreted. The discursive channel transmits concepts effectively but cannot convey the experiential dimension provided by the experiential, family-based channel; the result is a gap between what young people know about money and what they have actually experienced in relation to it. This has direct implications for the design of financial education as a communication strategy: it must take into account the different roles of communication channels, deliberately compensate for the experiential deficit of digital sources, and treat its audiences as active interpreters whose messages must be developmentally adapted.

The study is limited by a small, non-representative convenience sample (N = 20), which prevents the generalization of the findings to the entire population. Future research should include a larger and more diverse sample and apply longitudinal methods to monitor the long-term effects of digital socialization. We recommend that financial education programs focus more on the transition from technical skills to the development of critical and reflective attitudes toward money.

6 CONCLUSION

The research „Money through Children's Eyes" provides an in-depth insight into the semantic and symbolic structures of the economic thinking of the young generation. The study successfully integrated verbal and visual data, revealing that children are active and critical interpreters of the economic world around them.

The key findings highlight that while cognitive development sets the boundaries of understanding, the socialization environment—particularly the family and digital media—fills these boundaries with specific meanings and values. The transition to a cashless society and the digitalization of everyday life require a shift in pedagogical approaches. Financial literacy should not be treated merely as a set of mathematical skills but as a broader social and moral competence. The results of this pilot study serve as a basis for further research and the development of more effective, developmentally appropriate educational strategies that will empower young people for responsible functioning in a complex financial future.

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1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

CAN WE BRIDGE DIVIDES? DISCOURSE ON X DURING 2019 AND 2024 EUROPEAN ELECTIONS IN SLOVENIA

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ABSTRACT

As digital platforms increasingly mediate public discourse, many believe that ideological fragmentation threatens democratic debate and contributes to divided society. Yet, such discussions often remain on a normative level, while most empirical research examines single time points in large countries, limiting understanding of how fragmentation trajectories evolve over time, especially in smaller European democracies. This study explores how the communication landscape on X evolved between the 2019 and 2024 European elections in Slovenia, and what these structural patterns reveal about the possibilities and barriers for dialogue in digital public spheres. Using social network analysis, the study analysed over 100,000 tweets. I examined community structure, information flows, and temporal changes in network fragmentation during a period marked by platform transformation (Twitter to X) and global crises (COVID-19, war in Ukraine). Results reveal deep ideological clustering with minimal cross-group interaction in both periods. Fragmentation intensified remarkably: the right-wing cluster nearly doubled (+95%), while the left-wing cluster contracted (-18%). Network topology suggests a shift from isolated echo chambers to "echo platform" dynamics, where entire platform functions as ideological silos. These patterns emerge from platform affordances rewarding engagement, strategic communication choices, and media ecosystem shifts. Findings challenge optimistic assumptions about social media enabling dialogue and suggest the existence of structural barriers to cross-ideological deliberation. Yet, they also inform evidence-based interventions: algorithmic transparency, platform features and civic initiatives, and invite critical reflection on how European regulatory frameworks correspond to the empirical reality of the contemporary communication environment. As generative AI enters political communication, such evidence becomes essential for assessing future fragmentation dynamics and informing strategies to boost democratic resilience.

Keywords: *social media communication, polarization, echo chambers, X, European Elections*

1 INTRODUCTION

When social media emerged, technological networks enabling instantaneous global communication promised democratic renewal. A kind of modern-day *agora*, digital platforms would function as open spaces where citizens could engage in deliberative exchange of opinions and forge connections across social divides. Affordances enabled by networked communication promised to expand the public sphere beyond elite-dominated mass media (Castells 2008). Digital platforms, proponents argued, could at last realize ideals of the inclusive public sphere (Habermas 1962). Indeed, early empirical studies documented enhanced participation and cross-boundary dialogue on social media (Gil de Zúñiga et al. 2012).

This optimistic vision, however, has not materialized. As digital platforms matured and their role in political and public communication intensified, scholarly consensus shifted from optimism to concern (Carothers and O'Donohue 2019; Hong and Kim 2016). Echo chambers, driven by algorithmic curation, homophily and selective exposure, resulted in the emergence of ideologically segregated networks where users predominantly encounter like-minded perspectives (Sunstein 2017, 2001, 2007). Voices across academia, media, and civil society warned about the negative effects of such environments causing increased fragmentation, extremism, and lack of trust (Lewandowsky et al. 2017).

Concerns prompted a reconceptualization of the digital public sphere itself. Bruns (2023) speaks about "network of publics", claiming that the public sphere is now "irretrievably fractured into a multiplicity of online and offline, larger and smaller, more or less public spaces that frequently (and often serendipitously) overlap and intersect with one another" (2023, 70). This reconceptualization shifts analytical focus from individual-level exposure to platform-level structural dynamics that shape which publics form, persist, interact, or dissolve.

Shifts in digital landscape are influenced by changes in platform governance and legislation. The transition from Twitter to X demonstrates how platform governance can rapidly reshape communication networks. Elon Musk's acquisition triggered profound changes, most notably materializing in relaxed content moderation and algorithmic adjustments (Arun et al. 2024; Hickey et al. 2023; Tkacz and Gehl 2025). Meanwhile, increased public and scholarly concerns over the state of digital media landscape led to the push for oversight. Parliaments and legislatures in liberal democracies across the globe have the regulation of digital public sphere on their agendas (Chambers 2023). The European Union presented Digital Services Act (Regulation (EU) 2022/2065), a legislative package aimed at curbing potential negative effects of digital platforms on society. The 2019-2024 period thus offers an interesting comparison: the same political events (European elections) occurring before and after significant transformations.

Nevertheless, despite great stakes and scholarly attention, gaps remain in our understanding of how such transformations reshape communication networks. First, as most studies analyse single time points, we lack a more detailed, longitudinal understanding across various contexts. Second, research largely focuses on content and its exposure, but often neglects wider, platform-level, structural metrics that shape information flows in digital public spheres. Third, prominent research in the field mainly focuses on developments in the USA and larger Western European countries, while smaller European democracies remain understudied.

This study addresses these gaps with a comparative structural analysis of political discourse on X. Building on studies that analysed increasing fragmentation in other European contexts, such as Germany (Darius 2022) or Ireland (Pena et al. 2024), this research investigates whether similar patterns exist in Slovenia. The case study analyses how information cascades within and between partisan groups, guided by the research question: *How did the communication landscape on X evolve between the 2019 and 2024 European election campaigns in Slovenia?* Specifically, using network analysis, the study observes (1) clustering along ideological lines to reveal structural changes and (2) explores what do these structural patterns reveal about the possibilities and barriers for dialogue in digital public spheres. Comparative design captures not only the existence of fragmentation but also its evolution, empirically evaluating how balanced fragmentation in 2019 transformed into asymmetric platform dominance by 2024. Findings reveal strong asymmetry: the right-wing part of the network expanded by 95.3%, while the left-wing part declined by 18.2%, creating a structural imbalance, unprecedented in prior Slovenian election studies (Jesenšek and Verčič 2025).

2 THEORETICAL FRAMEWORK

2.1 From Echo Chambers to Structural Fragmentation

Fragmentation of (political) discourse may pose a challenge for contemporary democracies (Carothers and O'Donohue 2019). The concern is that fragmentation creates a structural basis of so-called parallel realities – sealed information environments of like-minded peers, where, often without opposing views, groups develop divergent interpretations of current events (Boxell et al. 2020; Weismueller et al. 2024; Yarchi et al. 2020). In such environment a place for inclusive public debate, where citizens could learn about a variety of different issues and opinions, is lost, and a democratic consensus becomes difficult (Kubin and von Sikorski 2021).

Fragmentation manifests in echo chambers (Sunstein 2001, 2007, 2017), isolated online environments characterized by homophily and selective exposure (Hartmann et al. 2025), and communicative fragmentation, driven by technological affordances and platform business models (Aral 2020). The concept is further refined by Nguyen (2020) as a "social epistemic structure from which other relevant voices have been actively excluded and discredited" (p. 2). This can be empirically observed as a community of users who predominantly communicate with each other and predominantly share content that conforms to the ideological views of the community. Empirical research documents such patterns across variety of contexts (Bastos et al. 2018; Darius 2022; Jasny et al. 2015), and across multiple platforms (Cinelli et al. 2020).

However, the term has drawn criticism, mostly due to poor definitions and oversimplification. Bruns (2019) argues that the concept is overstated and calls it "the dumbest metaphor of the Internet" (2024, 13). Other claim that the Internet is no more fragmented than the offline world, and that users regularly encounter diverse content even if they do not engage with it (Dubois and Blank 2018). Beyond these debates lies a more fundamental limitation: the vast majority of studies confirming the echo-chamber hypothesis capture single snapshots of the network structure. This methodological choice obscures a critical question: How do such environments evolve? Longitudinal studies remain rare, especially in the European space, which leaves us unable to determine whether and how fragmentation intensifies, stabilises, or decreases with time.

This comparative study distinguishes between two connected, albeit different, concepts: echo chambers and echo platforms. The first describes isolated pockets of like-minded users within otherwise diverse platform spaces, characterized by high internal connectivity but coexisting with other communities. The second concept, echo platforms, extends this to describe entire digital ecosystems becoming ideologically homogeneous, where a dominant cluster effectively captures the platform's overall structure (Di Martino et al. 2025). Consequently, entire social media platforms function as ideologically homogeneous niches within the broader networked public sphere. The echo platform concept thus extends Sunstein's concept of echo chambers by situating ideological homogeneity at the level of whole platforms rather than just within-platform communities. Echo platforms represent a departure from the positivistic vision of the Internet as a globally interconnected network with an undisturbed information flow, with implications for how information circulates and how public discourse is structured.

2.2 Networked Campaigning and Strategic Polarization

Social media fundamentally changed political communication. The internet became the primary communication technology of the 21st century, causing a shift from a broadcast model of communication, characterized by gatekeepers and one-to-many communication (Bennett and Iyengar 2008) to a networked model enabling many-to-many information flows (Klinger and Svensson 2015).

This networked media logic enables what Bennett and Segerberg (2013) call connective action, a form of political mobilisation that no longer requires formal organizational structures but instead relies on personalised sharing of content on social media platforms. The platforms not only transmit messages, but also provide conditions under which visibility, connection, and coordination occur. Information flows are mediated by algorithms prioritizing engaging content (Gillespie 2014; Huszár et al. 2022), which creates incentive structures that reward polarising communication over logical deliberation.

Political actors have learned to exploit these dynamics, making polarisation increasingly strategic (Ceia 2020). Politicians produce virality-driven polarising content, while dense networks of parti-

san supporters amplify these messages through interactions and shares. The resulting information cascades remain largely confined within like-minded communities (Bakshy et al. 2015; Katalinić et al. 2023). However, not all actors exploit these dynamics equally: right-wing and populist actors demonstrate greater effectiveness in exploiting networked communication structures, resulting in more successful content amplification than their left-wing counterparts (González-Bailón et al. 2022; Sandberg and Ihleb 2019). Several factors explain this asymmetry. First, right-wing users exhibit lower trust in mainstream media (Mourão et al. 2018), leading to greater reliance on social media and alternative sources (Benkler et al. 2018). Second, they employ communication styles characterised by emotional appeals, which align well with engagement-maximising algorithms (Engesser et al. 2016). Third, in many contexts, right-wing actors have developed alternative media ecosystems that complement social media presence through coordinated cross-platform strategies (Freelon et al. 2020). This body of research suggests that network asymmetries, where one ideological bloc dominates platform discourse, may not emerge organically but as a consequence of strategic exploitation of changing platform affordances.

These frameworks guide the analysis of Slovenian pre-election political discourse on X and help explain the observed transformation of the communication environment between 2019 and 2024.

3 METHODS

I used social network analysis (SNA) to examine communication patterns and the structure of online discussion on X. The data are gathered in two datasets (2019 and 2024), together consisting of 108,346 tweets (2019: 40,670 tweets, 2,845 unique users; 2024: 67,676 tweets, 3,081 unique users). In both years, data were collected in the period of one month before the election, using a set of 15 election-related hashtags and keywords. 2019 data were collected using the Twitter Streaming API between 26. 4. 2019 and 26. 5. 2019, and 2024 data were collected via a commercial provider with access to official X API between 9. 5. 2024 and 9. 6. 2024. Data collection complied with platform terms of use and GDPR principles. The 2019 data are published in an online repository (Jesenšek 2023), while the 2024 data can be made available upon request.

To observe communication flow, two retweet networks were constructed where nodes represent users, and directed edges represent retweets. To examine fragmentation of the network, I used Louvain algorithm (Dugué and Perez 2015) which identified various distinct communities based on users' communication patterns. Five largest communities in both datasets were examined in detail. The main characteristics of each community were determined based on the analysis of their top users, hashtags, and shared content, which informed the labelling of each community according to the prevailing political sentiment (right-wing, left-wing, anti-establishment).

Finally, information flows among communities were analysed by looking at the amount of homophilic and heterophilic interactions using the EI index (Krackhardt and Stern 1988). The measure provides a normalised comparison of the number of interactions within a community (internal or homophilic) with the number of interactions between one's own community and outside communities (external or heterophilic). The higher the index, the more content is able to flow to other parts of the network, and the less the community resembles an echo chamber.

Data analysis was performed with Python programming language (version 3.5.6.) using TSM module (Freelon 2018); network visualizations were created in Gephi (version 0.9.2.) using ForceAtlas2 algorithm (Jacomy et al. 2014) and Louvain community detection (Dugué and Perez 2015).

4 RESULTS

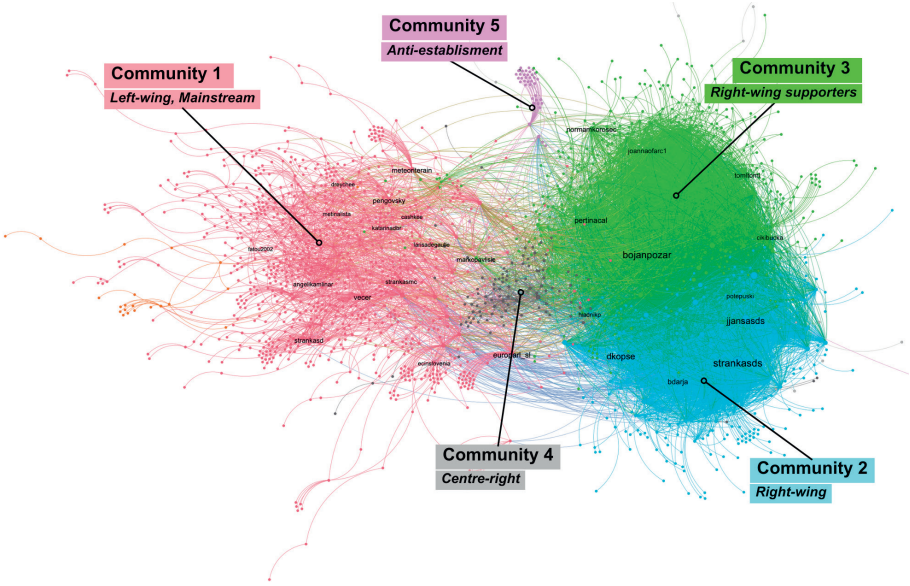
4.1 Network Structure 2019: Balanced Fragmentation

To examine communication flows, 28.041 retweets were mapped into a retweet network consisting of 2.854 nodes (users) and 14,483 unique edges (retweets). Observed network has an average path length of 5.515 and an average clustering coefficient of 0.103. Average path length is within expected range for social media networks, while higher clustering coefficient suggests the presence of clusters, each of which has dense connections within.

Community detection algorithm identified 49 distinct communities, out of which five biggest ones were closely examined (together representing 92% of all users). Communities 1, 2 and 3 were marked as "Right-wing", Community 3 as "Anti-establishment" and Community 4 as "Left-wing, mainstream".

Community 1 includes mainstream media, institutions, and left/centre-left parties and politicians. On the other hand, tightly connected right-wing communities 2 and 3 include politicians, party accounts and supporters of the biggest opposition party, as well as partisan media outlets. In addition, there is a visible centre-right community (Community 4) with connections to both parts of the network. The anti-establishment cluster is small and largely disconnected; its visibility in the overall discussion is marginal. The network is split into two distinct ideological clusters, reflecting traditional left/liberal and right/conservative division. This is clearly visible in the network visualisation (Figure 1), depicting information flows in the observed period.

Figure 1: Network visualisation, 2019. The network is split in two ideological blocs, relatively balanced in size.



(Source: Author's own visualization)

Both left- and right-wing clusters had strongly negative EI index (see Table 1), suggesting high levels of internal connectivity and limited external connections. The right-wing cluster has the most extreme EI index (-0.927), indicating it is the most isolated and echo chamber-like. The left-wing cluster also shows a high degree of internal connectivity (-0.684), suggesting it too forms a fairly strong echo chamber. These values indicate a polarised network structure, where each ideological group predominantly communicates within its own circle, thereby reinforcing existing views and limiting exposure to diverse perspectives.

Table 1: Detected clusters in the network, 2019

Cluster	Communities	Users (%)	E-I Index
Left-wing	1	39.3%	-0.684
Right-wing	2, 3, 4	50.7%	-0.927
Anti-establishment	5	3.2%	+0.441

(Source: Author's own work)

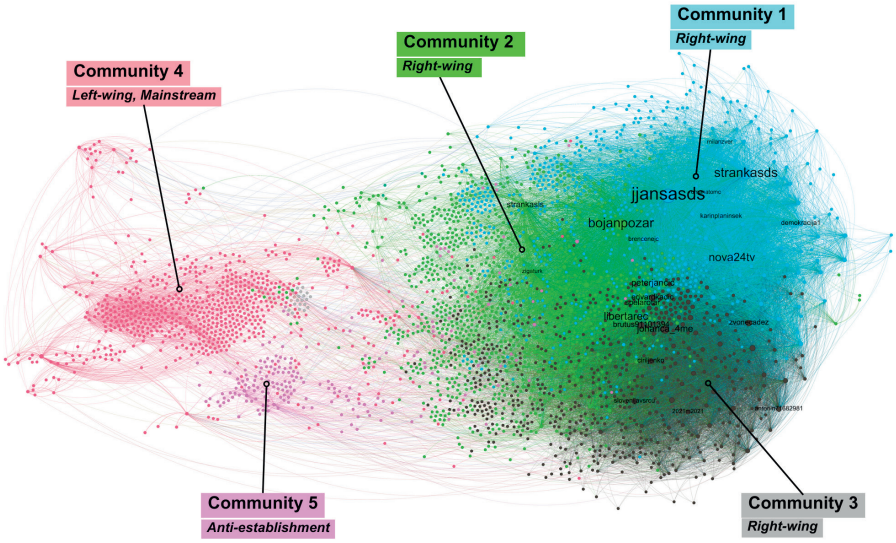
4.2 Network Structure 2024: Asymmetric Dominance

To examine the 2024 communication flows, 54.766 retweets were mapped into a retweet network consisting of 3.081 nodes (users) and 30.961 unique edges (retweets). Observed network has an average path length of 4.268 and an average clustering coefficient of 0.127, suggesting the presence of dense clusters, even more pronounced than in 2019.

Community detection identified 46 distinct communities, out of which five largest ones were closely examined (together representing 98% of all users). Communities 1, 2 and 3 were marked as "Right-wing", Community 3 as "Anti-establishment" and Community 4 as "Left-wing, mainstream". The right-wing cluster (communities 1, 2 and 3) includes accounts of visible right-wing political actors, supporters and partisan media outlets. The left-wing cluster is dominated by mainstream media accounts, journalists, and institutions. Several left-wing and liberal political parties belong to this part of the network but do not hold central positions in the discussion. The anti-establishment cluster features a varied mix of far-right and far-left influencers and content expressing distrust in institutions and political system.

Network visualisation (Figure 2) shows a polarised structure with prominent right-wing dominance. The network is still split into two distinct ideological clusters, reflecting traditional left/liberal and right/conservative divisions; however, the right-wing part, consisting of three densely connected communities, has become considerably larger (more users) and more active (greater number of retweets). The three right-wing communities together represent almost 70% of all users, whereas the left-wing part of the network shrunk considerably, now accounting for only 22.5% of all users. Right-wing communities are also tightly connected, meaning that content is easily disseminated among their members. Information flow between left and right ideological clusters is limited, indicating that users preferentially share content from like-minded peers, while cross-cutting diffusion has become even rarer.

Figure 2: Network visualization, 2024. Visible right-wing dominance in size, density, and centrality, and a smaller, less connected left-wing cluster. Information flow between these two clusters is limited.



(Source: Author's own visualization)

This was further confirmed by the low EI index score for the right-wing cluster (-0.952; see Table 2), indicating near-complete isolation. This suggests that users belonging to the ideologically right-wing part of the network effectively find themselves in an echo chamber (an index of -1 would mean that all connections are made between members of the same community). The

left-wing part of the network was slightly less isolated (EI index -0.608), which was likely due to connections with the anti-establishment community. The latter is smaller and is much more connected to the left-wing cluster than it is to the right, suggesting that the narratives circulated between mainstream left-wing and anti-establishment circles. The anti-establishment community is also the only one with a positive EI index (0.262), indicating that its users have more external than internal connections.

Table 2: Detected clusters in the network, 2024.

Cluster	Communities	Users (%)	E-I Index
Right-wing	1, 2, 3	69.7%	-0.952
Left-wing	4	22.5%	-0.608
Anti-establishment	5	6.1%	+0.262

(Source: Author's own work)

4.3 Temporal Evolution

Overall discourse volume has increased from 2019 to 2024 (+66% tweets), however the growth was highly asymmetric. While the right-wing nearly doubled in size (number of users) and intensity of communication (number of tweets and retweets), the left-wing declined. At the same time, the anti-establishment cluster expanded significantly; however, in absolute terms, it remained marginal compared to other groups (see Table 3).

Table 3: Users and clusters in the network; temporal evolution 2019-2024.

Cluster	2019 Users	2024 Users	Change	% Change
Right-wing	1,092	2,132	+1,040	+95.3%
Left-wing	846	692	-154	-18.2%
Anti-est.	68	189	+121	+177.9%

(Source: Author's own work)

The EI indices indicate the intensification of homophily, as large clusters of the network became more echo chamber-like. The network also showed signs of structural consolidation. In 2019, the presence of the centre-right community acted as a bridge between the left, mainstream, and right parts of the network. By 2024, these users had been largely absorbed into the tightly integrated right-wing block, with minimal interactions with other parts of the network.

5 DISCUSSION

Three key findings emerged: (1) Both periods exhibit structural polarization with minimal cross-ideological connectivity, signalling that the majority of political discussion happens among like-minded peers. (2) This fragmentation intensified in 2024. EI indices approaching -1 indicate near-complete echo chamber formation, where cross-ideological dialogue is not just rare but structurally hindered. (3) Network topology and community sizes developed asymmetrically. The right-wing cluster nearly doubled in size, while the left-wing cluster declined, representing a shift to what Di Martino et al. (2025) call *echo platforms*.

5.1 From Echo Chambers to Echo Platforms

The study reveals an extension of the echo chamber concept: between 2019 and 2024, X evolved from hosting multiple ideological communities (echo chambers) to structural dominance of a single cluster (echo platform). The distinction is important: while echo chambers describe isolated pockets within diverse platforms, echo platforms represent the entire platform becoming ideologically homogeneous silos, with one cluster achieving structural dominance. This segregation becomes so sharp that different groups of users effectively inhabit different platforms, with low awareness of cross-group content and virtually no meaningful interaction. Such a pattern aligns with research

describing the emergence of ideologically specialised platforms in fragmented media ecosystems (Freelon et al. 2020; Tangherlini 2025) and confirms what Di Martino et al. see as the "extension of the echo chamber phenomenon to the level of entire digital ecosystems" (2025, 3).

These findings also point to a changing ideological and political sphere in Slovenia. Between 2019 and 2024, the right-wing cluster expanded by 95.3%, while the left-wing cluster declined and went from being the biggest network cluster to a marginal one. Such asymmetrical growth aligns with the notion that the right-wing "has an advantage in the attention economy social media creates" (González-Bailón et al. 2022, 5). Slovenia is not an outlier – the right-wing advantage has been observed in various contexts, in Europe most notably in Germany (Darius 2022; Darius and Stephany 2019) and Spain (Rifà et al. 2024).

5.2 Explaining Asymmetry: A Multi-Factor Account

Growing asymmetry observed in Slovenia can be explained as a consequence of several interconnected mechanisms:

(1) Platform transformation. Transition from Twitter to X fundamentally altered platform's governance. Musk's "free speech absolutism" led to reduced content moderation, phase-out of fact-checking mechanisms, and algorithmic adjustments. Limited evidence suggests that these changes disproportionally benefit right-wing content (Huszár et al. 2022; Prama, Kalakonnavar, et al. 2025; Prama, Bagchi, et al. 2025). Furthermore, the shifts triggered user exodus, particularly among left-leaning users (Jeong et al. 2024; Peña-Fernández et al. 2025), which additionally accelerated X's ideological homogenisation (Freelon et al. 2020). While user exodus has been documented in the US context, it is likely that, to some degree, similar shifts took place in Slovenia,[1] as suggested by the observed decline in left-wing users (-18%).

(2) Strategic networked campaigning. Platform affordances create structural advantages for actors willing to deploy emotionally charged, divisive messaging. Prominent right-wing actors are generally more successful in leveraging these affordances to boost visibility and further their reach (Freelon et al. 2020; Rifà et al. 2024). Similar patterns have been observed in German and European elections (Darius 2022; Esteve Del Valle et al. 2022). The visibility and prominence of right-wing content in the Slovenian dataset point to the same direction. The findings suggest that right-wing growth (+95%) is not entirely organic, but, in part, the result of strategic communication of right-wing actors, who effectively used the platform to engage with their supporters.

(3) Media ecosystem changes. This strategic advantage was amplified by transformations in the media ecosystem. During the observed period, Slovenia experienced intensifying media-party parallelism, with the emergence of several partisan outlets as an answer to the mainstream media's traditional alignment with left-wing parties. Such alternative media ecosystems create cross-platform amplification networks enabling coordinated campaigns (Darius 2022; Ceia 2020). In a hybrid media system (Chadwick 2013), content from alternative outlets is amplified by partisan influencers and shared through X, creating self-reinforcing loops. On the other hand, left-leaning actors, traditionally relying on mainstream media, lacked equivalent infrastructure and cross-platform coordination, further contributing to asymmetric network expansion.

(4) Broader global developments. Between 2019 and 2024, the COVID-19 pandemic and war in Ukraine intensified polarisation around geopolitical issues and public health (Green et al. 2020), eroded trust in national and international institutions, experts, and democratic systems (Husenicova 2024), and boosted anti-establishment sentiments. Amid these developments, social media platforms operated as amplification channels for polarizing narratives, with systematic reviews and empirical studies identifying algorithmic and cognitive mechanisms that contributed to echo chambers and further fragmentation (Samet 2024).

1 For example, the party of PM Golob, Gibanje Svoboda, left the platform in 2022 ("Svoboda Zapušča Twitter" 2022). However, beyond observational evidence, there is no research confirming a wide-scale exodus of Slovenian users. This study found a smaller number of left-leaning users discussing the election in 2024 compared to 2019; but cannot conclude whether these users have merely became less active, or have abandoned the platform altogether.

5.3 Implications for Democratic Discourse

According to Habermasian view of the public sphere, democratic decision-making requires communicative spaces where citizens encounter diverse perspectives (Habermas 1989). The fragmented network structures documented here deviate from this idea, resembling Bruns' (2023) *network of publics:* a number of smaller, sometimes overlapping, interest-driven communities. The approach moves away from the European tradition of the public sphere and aligns more closely with the situational theory of publics (Grunig 1997). The latter originates in the American context, where Dewey and Blumer, as early as the beginning of the 20th century, defined publics as groups of people confronted with an issue (Dewey 1927). This concept of emerging, changing publics seems more suitable for describing developments in the contemporary hypermodern, networked communication environment (Self 2020).

Nevertheless, fragmentation of the unified public sphere does not necessarily mean that the space for discussion has shrunk. On the contrary, "it seems that the social web widens the public sphere, including those actors who do not communicate in accordance with the Habermasian conceptualisation of it" (Datts 2020, 73). In this sense, the public spheres enabled by social media platforms give voice to a wider variety of views than the mass media ever could – the dynamic that should, in theory, advance, not hinder, democratic processes. While digital platforms have expanded participation beyond traditional elite publics, this expansion has largely occurred within ideologically segregated networks. The negative EI indices documented in this dataset point to a loss of engaging with opposing views. In other words, while digital platforms empower a wide variety of actors, they do not always foster dialogue between them. As people increasingly turn to social media as their information source, this could become an issue because it prevents the formation of a shared reality, which makes democratic deliberation difficult.

5.4 Pathways to Democratic Resilience

Addressing fragmentation requires interventions across several interconnected levels (such as platform design, regulatory frameworks, political actors, civil society, etc.) to cultivate cross-cutting dialogue. Some of them are discussed below.

Despite platforms' huge influence, we know little about how algorithms govern content distribution. These algorithms operate with minimal or no external oversight, which makes any independent evaluation very difficult. Under the EU Digital Services Act, very large online platforms (called VLOPS, including X) must undergo independent audits to assess compliance with DSA obligations. Audits can cover aspects of platform design and algorithms (e.g. recommender systems); however, these efforts are encountering platform resistance as well as legal and technical constraints (Kaushal et al. 2024). Most often, large platforms, inclosing X, refuse to disclose any meaningful information regarding their algorithms due to proprietary reasons. Closing these gaps requires strengthening legal mandates, allowing access to data, and creating technical infrastructure that allows for independent algorithmic audits that are comparable and reproducible.

The European Union's Digital Services Act (DSA) requires very large platforms to assess *systemic risks* to democratic processes. However, its focus is mitigating content-level risks (like illegal content or disinformation), while network-level structural dynamics (like those observed in this study) remain ignored. A more effective regulation, as put by Thiel, "would not primarily refer to the moderation of content and communications, but take a broader look at how structures of power and domination are perpetuated in networked public spheres" (Thiel 2023, 74). Closing this gap requires integrating network-level metrics into platform accountability reports. Regulatory frameworks could set thresholds that trigger audits, disclosure, or design interventions as a last step. For example, recommender systems could boost cross-cutting content, introduce friction mechanisms for sharing highly partisan content, or de-prioritise uncivil discourse (Stray 2022). Limited experimental evidence shows that design interventions for social media recommender systems can reduce ideological bias (Haroon et al. 2022).

However, algorithmic interventions have not been tested at scale. Some research warns that exposing users to opposing views can increase polarisation (Bail et al. 2018), showing that poorly designed interventions may backfire. As noted by Stray, "any depolarization method based on select-

ing content according to a pre-existing theory may prove unable to cope with the radically diverse and dynamic contexts of a real recommender system" (2022, 11). Additionally, interventions risk accusations of limiting user autonomy and content censorship. A similar dilemma is already visible in discussions about AI, especially in election times. Legal scholars warn about dangers that new technologies may pose to democratic integrity – such as eroding trust, spreading disinformation, and cognitive warfare – while on the other hand there is also the danger of suppression of legitimate expression via government outreach and censorship as a reaction to these threats (Tomažič 2026). To balance harm reduction and protection of free speech, more focus should be put on evidence-based measures, targeting behaviour and content rather than ideology, with transparent platform architectures and consistently enforced rules that apply across online and offline discussion spaces (Duskin et al. 2024).

Even if successfully implemented, platform and regulatory interventions alone are insufficient, and their effectiveness ultimately depends on users' willingness for constructive engagement. To this end, media literacy programs are vital to teach citizens to recognize algorithmic curation and critically evaluate sources and perspectives. We should pay attention not only to the technological factors, but also be aware of messaging that leads to increased fragmentation. As put by Chambers, "exposing and publicly criticizing the political strategies of opinion manipulation used on social media and messaging apps is as important as opening up the black box of algorithmic curation" (2023, 67). Ultimately, no single intervention can curb the rising fragmentation. Coordinated, multi-level approaches show the most promise by aligning platform architecture, regulatory efforts and civic engagement. Whether democracies mobilise the political will to implement these pathways will determine if digital public spheres can support meaningful exchange of views – a necessity for a functioning and resilient society.

5.5 Limitations and Future Research

This study has some important limitations. First, the observational design allows us to document patterns, but cannot prove causality. Second, the findings are limited to a single country. Slovenia's small media market and political context may produce dynamics that differ from those of other democracies. Third, the comparison provides snapshots of two timeframes rather than continuous dynamics, potentially missing intermediate developments. Fourth, focusing on retweet networks puts a spotlight on what people choose to share, which might differ from what they encounter on the platform and/or decide to consume.

To address these shortcomings, future studies could engage in content discourse analysis to explore what kinds of narratives circulate within and between communities. Such research would offer better understanding from both quantitative and qualitative perspectives. Moreover, cross-platform studies could examine whether similar patterns exist across different social media platforms (for example, TikTok, Facebook, Reddit). Overall, more comparative and longitudinal research in smaller democracies is needed to better inform policies and practices. Lastly, studies could evaluate the effectiveness of algorithmic changes, moderation policies, and design interventions on network structure. Albeit more difficult due to the lack of data access, these could be achieved through platform collaboration or field experiments.

6 CONCLUSION

This study examined how communication on X evolved between the 2019 and 2024 European Parliament elections in Slovenia. Findings show that users preferentially share content from like-minded peers, while cross-cutting diffusion is rare. Fragmentation intensified remarkably: data reveals a transformation from relatively balanced fragmentation in 2019, where multiple ideological communities coexisted with moderate cross-cutting ties, to asymmetric platform dominance in 2024, characterized by right-wing cluster expansion (+95.3%), left-wing contraction (-18.2%), and intensified homophily (E-I indices approaching -1.0). These findings suggest that we are not just seeing echo chambers, but a shift toward "echo platforms".

The public spheres are increasingly fragmented and polarized, which can be attributed to digital platform architecture driven by business goals of maximizing attention; communication strate-

gies of political actors making use of such architecture; and regulation struggling to catch up. It is clear that the optimistic view of digital platforms fostering democratic discourse by establishing an open space for deliberation is not materializing. The empirical reality of the contemporary digital communication landscape shows that the idea of one unified public sphere (if it ever existed) has been replaced by a multitude of smaller, overlapping and ever-changing public spaces. This does not mean, however, that public discourse must collapse into isolated echo chambers and parallel realities. The open nature of digital platforms theoretically allows participation across public spaces, though this study shows such cross-cutting engagement is rare.

Yet, the question is not only if digital platforms can support democratic dialogue, but also if we will make the choices that enable them to do so. Balanced governance, algorithm transparency, and sensible platform regulation that curbs malign communication practices while maintaining free speech will be needed to ensure that digital platforms continue to provide public spaces for deliberation, allowing us to bridge, rather than deepen, divides. Such interventions need to be based not on assumptions, ideology, or moral panic, but on robust empirical data. Looking forward, we need more comparable, longitudinal and cross-platform research examining social media fragmentation in a variety of contexts. To be able to shape effective solutions to the challenges at hand, we must first be able to understand and explain what is happening in the contemporary communications environment. The transformation of our digital public spheres remains an ongoing project whose outcomes depend on the choices we make today.

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AI DISCLOSURE:

The final version of this manuscript was reviewed using Paperpal, an AI-based tool employed solely for language and grammar check. Generative AI was not used for any intellectual content, analysis, and conclusions, which are the original work of the author.

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FROM (IN)VISIBILITY TO AWARENESS: PUBLIC TRANSPORT HARASSMENT IN ZAGREB — DOCUMENTING THE PROBLEM, ANALYZING THE 2025 CITY CAMPAIGN AND ITS MEDIA IMPACT

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ABSTRACT

Violence against women is on the rise, as evidenced by numerous devastating statistics. Experts believe that the real situation is much worse, since victims mostly remain silent and do not report violence. The reasons for this are multiple: fear due to what they have experienced, shame and guilt, stigmatization by the environment and the media, as well as distrust in institutions represent major obstacles in dealing with an unpleasant and often traumatic experience. At the same time, the increase of violence in society and the media's treatment of it can lead to desensitization of recipients, as well as the normalization of such a condition, which is often manifested by the passivity of participants. This is also supported by the increase of sexual harassment of women and girls in Zagreb's public transport, whose traumatic experiences, shared on social networks or forums, are mostly published in local media. An invisible social problem is thus slowly becoming a news topic aimed at raising public awareness. In November 2025, the month of combating violence against women, the City of Zagreb, following the example of other European cities, and in cooperation with the Zagreb Electric Tram (ZET) and the Zagreb Police Department (PUZ), launched a communication campaign aimed at combating sexual harassment and violence against women. The main task is to help victims, but also to educate potential witnesses of the event and ensure safety in public city transport. The aim of the paper is to provide a comparative overview of the Zagreb campaign on combating violence against women with previously implemented European campaigns in order to identify similarities and differences, and to formulate recommendations for strengthening awareness on this topic. Furthermore, the second part of the paper presents a case study describing the implementation of the campaign (key messages, distribution channels and target audience).

Keywords: *violence against women, victims, sexual harassment, public transport, campaign*

1 INTRODUCTION

According to a Gallup survey from 2011 (in Stop Street Harassment n.d.), three out of five women confirmed that they had been victims of abuse in public transport. Overcrowded transport, close physical proximity, transit environments, and anonymity contribute to the incidence of criminal offenses. The online safety map Free To Be enables women and girls to mark safe and unsafe locations, which resulted in creating a list of the safest and most unsafe cities in the world. The benefits of highlighting Gender-Based Violence and Harassment (GBVH) indicators include ensuring the well-being of passengers and drivers, avoiding reputational damage, building trust, economic growth, and improving the overall health and safety. However, risk factors should also be emphasized: poor lighting, unsupervised areas, the absence of an emergency button, overcrowding, and the lack of a code of conduct.

Media reports on the harassment of girls and women in public transport have unpleasantly surprised the citizens of Zagreb. Traumatic experiences are being shared on forums and chat groups by victims in order to warn that anyone can become one. Their written testimonies can be found in certain city sections of mainstream media or in short news within the crime reports, which in 2025 recorded 19 femicides that shocked the public and demonstrated a strong presence of gender-based violence. Nevertheless, it is encouraging that some local media outlets devoted significantly more media coverage to this issue, demonstrating their informative role within the local community.

Raising public awareness on this problem is becoming an important task for the community, but also for the society in general Communication campaigns play a significant role; key messages and visuals serve as a supporting emotional appeal as well as education for participants and victims of harassment, who most often choose silence and non-reporting. This paper presents a campaign implemented in November 2025 with the support of the City of Zagreb, Zagreb Electric Tram, and the Zagreb Police Department, as part of broader efforts to eliminate violence against women. The case study examines the campaign's implementation as well as its impact on the public.

2 SEXUAL HARASSMENT FACED BY WOMEN IN PUBLIC SPACES

Horvat and Perasović Cigrovski state that the topic of harassment of women in public places has been largely marginalized, mostly due to the focus of researchers on sexual harassment and harassment in the workplace (Fairchild and Rudman 2008; Lenton et al. 1999 in Horvat and Perasović Cigrovski 2014, 294). There are many reasons for this situation, and the following stand out: a) the definition of public space and the easy understanding that harassment is not a problem if there is no physical attack and b) the understanding of the formality of public space (Lenton et al. 1999 in Horvat and Perasović Cigrovski 2014, 294).

Historical analysis has shown that women are more often blamed for violence that occurred because of their way of dressing or behaving since the late 19th and early 20th centuries. However, it is difficult to compare research due to the different methodologies used, as well as the objectives: the frequency of exposure to harassment in Canada (Lenton et al. 1999 in Horvat and Perasović Cigrovski 2014, 294), forms of harassment (Hunter 2012 in Horvat and Perasović Cigrovski 2014, 303), experiences with harassment in Turkey and Iran (Kearl 2010; Lahsaeizadeh and Yousefinejad 2012 in Pina et al. 2009, 127 in Horvat and Perasović Cigrovski 2014, 297), the profile of harassers (Macmillan et al. 2000 in Horvat and Perasović Cigrovski 2014, 302).

The consequences of harassment of women in public places can be observed through a) the impact on the individual in the context of fear of violence, changes in behavior (from feelings of flattery for less aggressive interactions to feelings of life threat), as well as economic consequences (job change), and b) the impact on society as a whole (distance between the sexes, women's dependence on men, subordination, objectification of women, trivialization of attacks, the relationship between gender and sex as categories) (Horvat and Perasović Cigrovski 2014, 306; Yuval-Davis 2004, 66-67 in Marin 2019, 6). Prevention is possible through recognizing the problem, empowering women to self-defense and seek help, education and sanctions for those who carry out harassment, and finally changing social norms (Horvat and Perasović Cigrovski 2014, 306).

An overview of previous research shows that the primary focus of authors in the 70s and 80s was on the sexual abuse of women in public space (MacKinnon 1979; Wekerle and Rutherford 1987 in King et al. 2025). A decade later, the research focus shifted to the study of the emotional dimension and perception of traumatic experience (Pain 1991), and in the period from 2015 to 2020, interest in this topic in the scientific community doubled (Fileborn and O'Neill 2023 in King et al. 2025, 2). So Allen et al. (2018) investigated the types of harassment in public transport, but also outside it in three cities (Buenos Aires, Santiago and Quito), as well as the difference in the perception of the depth of trauma in male and female victims of harassment. The role of fear as a motivating factor in the decision to use public transport is the focus of a study investigating women's perceptions of safety in public transport in Chile and Venezuela (Korn 2018).

The first qualitative study on this topic in Croatia was conducted by Marin (2019), which also identified differences in the perception of experiences by gender. Women's experiences are more negative and traumatic due to the perception of a threat to physical space and identity (Požgaj 2023, 16) with sometimes divided or contradictory feelings. This contributes to the creation of doubts in their own assessments of the event or perpetrator and the increase in the share of unreported cases (Šimunec 2025, 36) and the gradual normalization of this form of deviant behaviour. At the same time, men perceive such experiences as surprising, insignificant or funny (Marin 2019, 22-28). Furthermore, most female victims of harassment confirm feelings of shame and helplessness (Tanasković and Račeta 2007; Balenović et al. 2000) because the incident occurred in front of witnesses who did not react, which confirms the findings of previous research on passive bystanders (Shoaf and Shaw 2024). Therefore, most victims apply various self-protection strategies: from avoiding public transport, better self-protection to carrying tear gas and tasers (Šimunec 2025, 23).

3 LEGISLATIVE FRAMEWORK FOR COMBATING HARASSMENT: A COMPARATIVE OVERVIEW OF EUROPEAN AND CROATIAN LEGISLATION

Sexual harassment of women is defined in European legislation through the prohibition of such behavior in the context of discrimination and by establishing obligations for Member States. Directive 2002/73/EC was the first European act to define and prohibit sexual harassment as a form of sex-based discrimination. A more detailed elaboration is provided in Directive 2006/54/EC. Furthermore, the Equal Treatment Directive (Directive 2006/54/EC) emphasizes the importance of implementing equal treatment for women and men in employment and occupational definitions. This directive also highlights harassment and sexual harassment as forms of prohibited discrimination.

In 2024, Directive 2024/1385 on Combating Violence Against Women and Domestic Violence, was adopted as the first European act specifically targeting gender-based violence against women, encompassing broader contexts beyond the workplace, such as public spaces. This act requires the criminalization of certain forms of violence against women and introduces preventive measures, which must be implemented in national legislation. The document addresses violence and abuse against women as part of broader gender-based violence and establishes a set of standards for prevention, protection, and victim support.

The European Charter of Fundamental Rights, which is legally binding for European institutions and Member States, treats sexual harassment as a form of prohibited discriminatory behavior within specific articles. Article 21 prohibits any form of sex-based discrimination, while Article 23 emphasizes the importance of gender equality in all areas of activity (EU Charter of Fundamental Rights 2000, Articles 21 and 23).

The Constitution of the Republic of Croatia recognizes and defines gender equality as the highest value of the constitutional order (Art. 3) (Šarin and Gržetić 2023) and emphasizes equality before the law regardless of sex (Art. 14). The Anti-Discrimination Act (2008) and Law on Amendments to the Anti-Discrimination Act (2012) broadly defines discrimination and prohibits sexual harassment as a discriminatory act outside the workplace. Furthermore, the Gender Equality Act (NN 82/08, 69/17) in Article 8 prohibits any harassment and sexual harassment in all spheres of activity (education, work, employment), considering it a form of discrimination. The law prescribes fines of up to €4,000 for violations. However, Šimunec (2025) warns that these two laws do not explicitly address the issue of street harassment.

The definition of harassment of women in public spaces is broad due to numerous verbal and physical behaviors aimed at demeaning women. It is an interaction imposed by a man, aimed at creating an unequal, subordinating relationship that a woman often cannot interrupt on her own terms or at her own pace (Kissling 1991; Di Leonardo 1981 in Horvat and Perasović Cigrovski 2014, 295-297).

The Labor Act (NN 93/14, 127/17, 98/19, and 151/22) primarily regulates employment relationships in the Republic of Croatia and emphasizes the obligation of employers to ensure equal working conditions, particularly in the context of equal pay (Article 91) and work of equal value, which entails comparability of qualifications, responsibilities, and working conditions. The Labor Act prohibits discrimination in the labor market regarding recruitment, promotion, and working conditions. Employers bear the responsibility for preventing and sanctioning such behavior. The Criminal Code criminalizes sexual harassment as a separate offense in Article 156, defining it through verbal, non-verbal, and physical manifestations that may cause fear or humiliation in the victim. In describing the legal framework in Croatia, Požgaj notes that reforms have been slow and largely symbolic. The 2013 Criminal Code defined sexual harassment, and subsequent amendments increased the prison sentence by one year (amendments to the Criminal Code in 2019), with the current law still in force as of 2023 (Požgaj 2023, 11). The prescribed prison sentence is up to two years, and for vulnerable groups, the penalty may be higher. This legislation elevated sexual harassment to a higher legal level by criminalizing perpetrators and extending its scope beyond the workplace, potentially including public spaces and public transportation. Finally, the Act on the Protection against Domestic Violence (NN 70/2017) defines violence as a form of interaction within the family or household community, specifying its members and the types of penalties for committing certain offenses. Harassment is treated as a form of violence, including intrusive behavior (Art. 140 of the Criminal Code) and sexual harassment (Art. 156 of the Criminal Code), and it is not strictly limited to intimate relations.

4 COMMUNICATION CAMPAIGNS TO STRENGTHEN WOMEN'S SAFETY IN PUBLIC TRANSPORT

Violence against women in public transportation reflects patriarchal structures and power dynamics (Roth 1999; Levy 2013; Lefebvre 1974 in Korn 2018, 7). Additionally, due to their roles as mothers and homemakers, women often depend on public transportation, and threats of violence influence their patterns of public transit usage (Rainero 2010 in Korn 2018, 7). Korn highlights a gap in the literature regarding the "right of women to the city" and its connection to sexual violence. She also points to various city initiatives aimed at addressing this problem, including "improvements in transport infrastructure, relationships with the police, and raising public awareness" (2018, 8). Toronto, for example, has implemented infrastructural improvements to ensure better visibility of passengers (Loukaitou-Sideris 2009, 42 in Korn 2018, 8), which also serves to deter potential perpetrators (Whitzman et al. 2013 in Korn 2018, 8). Furthermore, strengthening the judicial sector is a crucial component, as seen in Ecuador, while preventive public campaigns can also play an important role in reducing harassment and violence.

Newton describes the *"Report It to Stop It" – Project Guardian* campaign which has been present in London since 2013, aiming to reduce unwanted sexual behavior in public transportation. The project involves the transport police, representatives of transport companies, and other branches of the police. The campaign's objective was to create a dedicated website and a hashtag on the social media platform Twitter (now X) to launch the initiative publicly. Additionally, a dedicated hotline was established for reporting sexual harassment. Simultaneously, the campaign was implemented on-site, where leaflets were distributed to citizens in order to raise awareness about the initiative. Training was also provided to call center employees handling reports of incidents. Furthermore, the campaign launched in 2015 aimed to encourage women aged 17 to 34 to report incidents of harassment. The campaign was conducted in multiple phases, with dissemination carried out through video materials and leaflets. Results showed that with each new phase of the campaign, the number of reported incidents increased. This has long-term effects in terms of more efficient allocation of law enforcement resources, the fact that most perpetrators are repeat offenders, the utility of even minimal data for tracking perpetrators, and the empowerment of transport staff, which contributes to better supporting victims coping with trauma.

Figure 1: Report it to stop it.



(Source: *The Met's New "Report It to Stop It" Campaign* 2015)

Regarding preventive behavior, Newton refers to the international study *Transit Crime and Sexual Violence in Cities*, edited by Vania Ceccato and Anastasia Loukaitou-Sideris (2020), which was conducted in 18 cities across 18 countries on six continents. The aim of the study was to investigate the implementation of preventive behaviors in public transportation in: Guangzhou (China), Los Angeles (USA), Paris (France), and Vancouver (Canada). The results showed that avoidance is the primary strategy used on buses and trains. Gender analysis of travel frequency revealed that women travel more often and are more likely to feel unsafe. Indicators such as gender, perceived safety at night, and travel frequency proved to be significant predictors of public transportation use.

The International Association of Public Transport (UITP) provides an overview of 15 global campaigns aimed at combating gender-based violence. For example, the *Kom op Amsterdam!* (*Come on Amsterdam!*) campaign called on city residents to take action against gender-based violence. The campaign included numerous experiences with gender-based violence and provided guidelines for reporting offenses. It involved advertisements, posters, and video materials, which were viewed more than 2.8 million times (Gemeente Amsterdam n.d.).

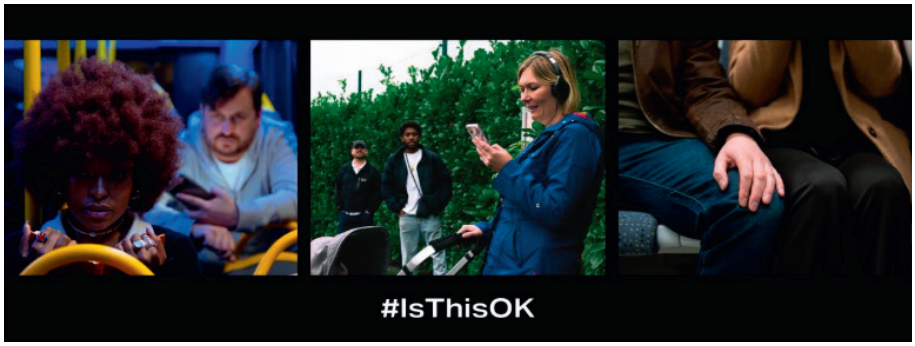
Figure 2: Come on Amsterdam!



(Source: Gemeente Amsterdam n.d.)

Furthermore, the *IsThisOk?* campaign, conducted in 2021 in Greater Manchester, brought together over 65 organizations with the aim of sharing experiences and raising awareness of unwanted behavior toward women in public transport. Additional initiatives included a live chat for reporting negative experiences, requests for improved lighting, and the elimination of unwanted behavior in educational institutions (International Association of Public Transport 2025). The campaign was based on a series of videos illustrating types of unwanted behavior in public transport, which were further promoted through digital advertising. Moreover, the campaign sought to influence the awareness of boys and men regarding unacceptable behavior toward women, encouraging them not to remain passive bystanders but to report any observed incidents (Transport for Greater Manchester n.d.).

Figure 3: IsThisOk?



(Source: Transport for Greater Manchester n.d.)

Below is an overview of the campaign against sexual harassment of women in public transport in Zagreb.

5 RESEARCH METHODOLOGY

5.1 Objective and research questions

In November 2025 the City of Zagreb, following the example of other European cities and in cooperation with the Zagreb Electric Tram and the Zagreb Police Department, launched a communication campaign aimed at combating sexual harassment and violence against women. Unlike many preventive campaigns, which predominantly take place on social media, this campaign was spatially and situationally focused, implemented inside public transport vehicles (City of Zagreb 2025). Considering the campaign was not digitally oriented, the communication took place within the physical space of public transport and directly targeted actual users in the moment of potential risk.

Figure 4: Poster example in public transport



(Source: Policijska uprava zagrebačka 2025)

The objectives of this study are to analyze the *"I Have Never"* campaign aimed at raising awareness of harassment of women in public transport through media and social media, to investigate the campaign's key messages, and to present the communication tools used, the campaign's tone, as well as the presence of guidelines and instructions for reporting harassment.

Accordingly, the following research questions were formulated:

- How was the campaign represented in local media coverage?
- What communication messages and tools were used in the campaign?
- How does the campaign frame the problem of sexual harassment in public transport? How are victims and witnesses encouraged to respond to incidents of harassment?

5.2 Research Sample

The units of analysis consisted of campaign communication materials (QR code tags, educational posters, public messages) and online media articles reporting on the campaign. The analytical sample included:

- official campaign materials published by the City of Zagreb
- educational posters available through QR codes
- public campaign messages displayed in public transport
- local online media articles published between 21 and 30 November 2025 that reported on the campaign.

Media articles were identified through keyword searches using the campaign title and terms related to sexual harassment in public transport. The final sample consisted of a total of eight articles published by 7 media outlets during the campaign period. The selected materials represent the campaign's main communication outputs and publicly available media coverage.

5.3 Analytical Procedure

The campaign materials were analysed using qualitative content analysis (Wimmer and Dominick 2014). The analysis examined emotional framing, communication objectives, target audiences, and calls to action. Table 1 presents the categories and the aspects examined within each category.

Table 1: Content Analysis Framework

Category	What was examined
Communication objective	Whether messages focused on awareness, prevention or reporting
Target audience	Whether messages addressed victims, witnesses or the general public
Emotional framing	Presence of fear, empathy, solidarity or empowerment
Call to action	Presence of instructions for reporting or intervention

(Source: Author's work)

Communication objectives were identified based on whether the dominant message of each material focused on awareness-raising, prevention, or reporting and intervention. Target audiences were determined by examining explicit and implicit references to intended recipients, such as victims, witnesses, or the general public. Emotional framing was analyzed by identifying the presence of affective appeals, including fear, empathy, solidarity, and empowerment. Call-to-action elements were coded when materials contained explicit instructions or recommendations for behavioral response, such as reporting incidents or intervening as a bystander.

5.4 Campaign Implementation Analysis

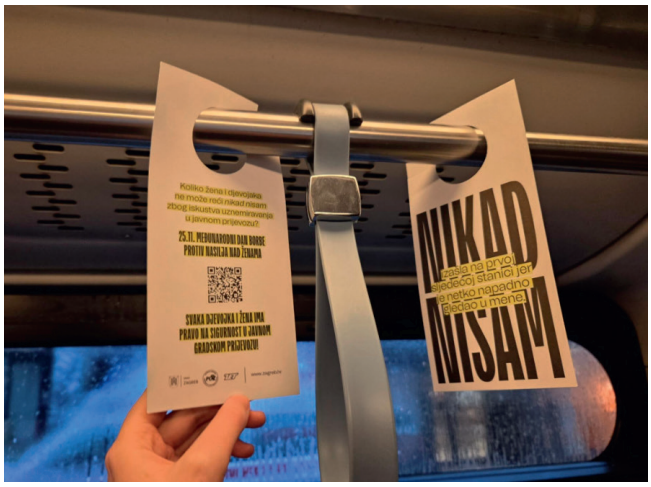
The campaign was conducted from 21 to 25 November 2025; although short in duration, the final day of the campaign carries symbolically strong significance as it coincides with the International Day for the Elimination of Violence Against Women.

Considering the limited duration of the initiative, the overall coverage can be considered constrained; however, the location of the campaign and the high daily frequency of public transport users must be taken into account, as the campaign's key messages are repeated multiple times along citizens' daily routes and routines.

The main communication tool used in public transport consists of tags with QR codes. This requires recipients to actively access the content rather than passively receive it. Such a communication ap-

proach can be effective in terms of discretion and individual information delivery, especially in the context of the sensitive topic of sexual harassment. However, this approach also limits the campaign, as it requires a certain level of sense of security, time, space, and digital literacy for active participation. In this way, the issue of sexual harassment becomes visible in public spaces, but its deeper understanding remains available only to active recipients of the message.

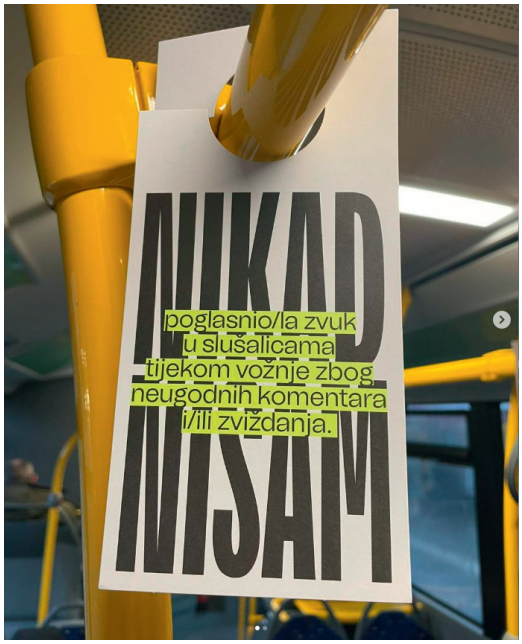
Figure 5: QR tags in public transport



(Source: Kovačević and Hina 2025)

The poster linked to the QR code consists of two main sections. The first part features a series of situations experienced by women in public transport—short phrases describing uncomfortable and frightening situations. The phrases used in this section are not abstract; they depict everyday, concrete experiences such as: "I have never got off at the next stop because someone was staring at me aggressively" or "I have never pretended not to see someone secretly taking photos on the tram."

Figure 6: Poster example in public transport



(Source: Zagreb.info 2025)

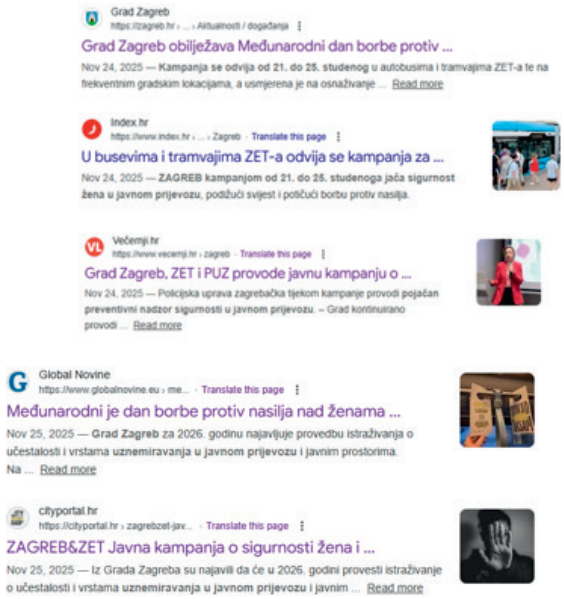
This choice of language creates an emotional connection with public transport users who may have experienced similar situations. At the same time, using a more formal, academic tone could be perceived by the audience as detached. Additionally, this approach emphasizes that harassment does not happen to someone else but occurs in everyday situations. The second part of the poster contains instructions on how to behave when harassment occurs. (Zagreb.hr. n.d.)

At the very bottom, it is stated "Every girl and woman has the right to safety in public transport!" (Zagreb.hr. n.d.) This sentence not only describes the problem but frames safety as a right rather than a privilege, positioning the right to safety as a social and legal obligation toward women and girls.

5.5 (In)Visibility of the campaign and public response

The visibility of the campaign is analyzed through the presence of the topic in online media during the campaign period. Local portals reported on the campaign, publishing articles that closely mirrored the City of Zagreb's official press releases.

Figure 7: Media outlets reporting on the topic



(Source: Author's own screenshot of Google Search results, January 26, 2026)

Since the media largely adopted the institutional discourse, the campaign was communicated to the public primarily as a symbolic and occasion-based activity linked to the observance of a specific date, rather than as part of a long-term strategy.

A deeper analysis of the problem, inclusion of women's experiences, or the initiation of a public debate on sexual harassment in public transport was omitted. The campaign was visible in the physical space of public transport, but its media visibility remained limited to brief, informational reporting without further development of the topic.

The absence of a broader public debate should not necessarily be interpreted as a failure of the campaign, but rather as an indicator of the deeply ingrained social normalization of sexual harassment and the discomfort in publicly discussing this issue.

6 CONCLUSION

Based on the conducted analysis, it can be concluded that the Zagreb campaign is symbolically strong and content-wise relevant. By placing communication messages inside trams and buses, the campaign made sexual harassment visible within the everyday experience of public transport users, thereby at least partially disrupting the pattern of its social normalization and silencing.

At the same time, the analysis points to certain limitations of the campaign, primarily regarding its duration and strategic design. The short-term implementation resulted in limited public resonance. Although the campaign was highly present in the physical space of public transport, its stronger presence in the media and digital sphere was lacking, which reduced the potential for initiating a broader public debate.

An additional limitation concerns the absence of clearly defined objectives and measurable indicators of success, which made precise evaluation of its impact impossible. While the campaign included normative and educational goals, without pre-established metrics (such as reach, reactions, or frequency of QR code scans), it is not possible to assess the extent to which it influenced awareness, bystander behavior, or the sense of safety among public transport users.

Accordingly, several measures can improve future initiatives. Extending the campaign would increase its impact and message recognition among public transport users. Furthermore, combining offline and online channels would enhance visibility and encourage public engagement through digital platforms. Finally, repeating the campaign outside symbolic dates could contribute to the visibility of sexual harassment in public transport as an ongoing issue rather than a temporary concern.

In this way, the campaign could evolve from a short-term symbolic intervention in the public space into a long-term, strategically designed communication framework aimed at raising awareness, empowering victims and encouraging active bystander engagement.

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1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

CUSTOMER CENTRICITY IN THE DIGITAL AGE: A CASE STUDY APPROACH

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ABSTRACT

Customer centricity has long been a cornerstone of strategic marketing, yet the rapid spread of digital technologies has significantly transformed its scope and practice. This paper provides an overview of the customer centricity literature and examines how digitalization has changed and expanded customer centricity approaches, including personalization and hyper-personalization. As data-driven tools, algorithms and real-time analytics evolve, companies can predict customers' needs and create more tailored value propositions for their customers. Alongside these developments, influencers have emerged as key actors who bridge companies and customers by shaping perceptions, building trust and translating brand messages into relatable content. At the same time, influencers themselves adopt customer centric strategies to better engage with their followers and how this engagement can also create parasocial relationships with them. In the methodological part, the paper illustrates these dynamics through a detailed case study. The aim of this study is to better understand how data-driven tools and real-time analytics increase customer centricity. Apart from this, the study also examines the influencer side, examining how customer centricity can enhance the formation of parasocial relationships. The findings aim to contribute to the deeper understanding of customer centricity in the digital age and highlight how both companies and influencers can leverage these practices to better serve their customers and communities. On the company side, customer centricity is a strategic tool for customer engagement and loyalty. The findings also show that brand-owning influencers can use their social media platforms to include followers in product design, this seemingly two-sided interaction leads to the formation of parasocial relationships.

Keywords: *customer centricity, marketing, parasocial relationships, influencer, consumer behavior*

1 INTRODUCTION

Customers are really important for companies. They determine whether a business prospers (Drucker 1954). And so, it is important that companies are not trying to sell products, but instead they focus on the needs of their customers (Levitt 1960). There is a difference between product and customer centricity. Product centricity means that the goal of the company is to sell products to anybody who pays, and it is transaction oriented and has an internal focus such as product development or gaining a bigger market share (Shah et al. 2006). On the other hand, customer centricity is when the company wants to serve its customers, and the processes are more relationship oriented, and they also have external focus, for example increasing loyalty or customer relations (Shah et al. 2006).

The customer centric marketing needs an organization that is also customer centric (Sheth et al. 2000). The goal of customer centricity is to discover the real needs of customers and to understand and serve these needs (Sheth et al. 2000; Zhang et al. 2023). When an organization is customer centric, they organize all their functions around customer centricity, and marketing is integrated with all other functions (Sheth et al. 2000). Customers participate in product development and there is a shared value creation, co-creation. And in cases when the company realizes they can't effectively serve their customers; it is better to outsource them to make them content (Sheth et al. 2000).

We live in the age of digitalization, and this also affects customer centricity (Rekettye and Rekettye 2019). Mobil devices are spreading, and almost everyone uses social media. This can help build communities and provides opportunity to a shared value creation and collaboration (Deighton 2023). There are huge databases, and with their analysis, companies can make personalized offers to their customers (Qu 2024). Many use gamification to further encourage the use of their platforms, and therefore they can collect more user data (Aunkofer 2018; Riedmann-Streitz 2018). Algorithms can predict and guide consumption, with real time data analysis and predictions (Qu 2024). The use of AI is also increasing, it can be used in customer service, through AI chatbots and even to optimize the supply chain or to assist product development. With the spread of 5G, the Internet of Things was made possible, devices now can communicate with each other making the customers' lives easier (Rekettye and Rekettye 2019).

On one side, influencers as content creators must consider feedback from followers to stay relevant for them. This makes them customize their content for their followers to boost engagement (van der Harst and Angelopoulos 2024). They react and comment to followers and therefore form connections with them and these connections lead to the formation of parasocial relationships (Ballester et al. 2025). On the other hand, influencers also act as a bridge between consumers and companies. They can transfer trust placed in them to the endorsed products and brands (Reinikainen et al. 2020). In some sense they could also be considered as peers of the consumers, so their review can count as peer review (Guo et al. 2022; Zhang et al. 2023).

The aim of this study is to explore how customer centricity operates in digital environments and how customer centric practices can be implemented within influencer-led brands. Particular attention is given to the role of social media platforms in facilitating continuous interaction, audience participation, and co-creation between influencers and their followers. Furthermore, the study examines how these customer centric practices contribute to community engagement and the formation of parasocial relationships. Through a qualitative case study of Cassey Ho and the POPFLEX brand, the research seeks to illustrate the interconnected relationships between customer centricity, community engagement, parasocial relationships, and customer loyalty in the digital age.

2 METHODS

This study applies a qualitative research approach using a single-case study design to explore how data-driven customer centricity operates in an influencer-led brand and how it contributes to customer engagement and parasocial relationship formation. A qualitative methodology is appropriate given the exploratory nature of the research and its focus on understanding processes and meanings in a real-life digital context.

The case study focuses on Cassey Ho, fitness influencer and founder of POPFLEX, selected through purposive sampling due to her long-term and transparent use of social media and her customer

centric practices and active audience involvement in product development. The study is based on secondary qualitative data collected from publicly available sources between 2009 and 2026, including social media content (YouTube, Instagram, TikTok), brand-related posts, and publicly available interviews and media appearances. Data collection focused on publicly available content that documented key stages in the development of the Blogilates and POPFLEX brands, including product launches, community engagement initiatives, and discussions of product development.

Relevant video and textual content were reviewed. The analysis focused on themes related to customer centricity, personalization, community engagement, and parasocial interaction. As the study is qualitative, no statistical or quantitative analysis was applied. The research relied exclusively on publicly available data and did not involve direct interaction with participants; therefore, formal ethical approval was not required. The findings are context-specific and limited to a single case, which restricts generalizability but allows for in-depth insight into customer centric practices in a digital influencer context.

The analysis followed an iterative and interpretive approach to qualitative data examination. Publicly available materials, including social media content, interviews, and media appearances, were reviewed repeatedly to identify relevant practices related to customer centricity and influencer-audience interaction. During this process, systematic notes were taken to document recurring patterns and meaningful examples across the dataset. These observations were gradually organized into higher-order thematic categories, including customer co-creation, responsiveness to audience feedback, community engagement, authenticity in content creation, and signs of parasocial relationship formation. The identified themes were then interpreted in relation to established theoretical frameworks in customer centricity, influencer marketing, and parasocial relationship literature, allowing for a structured connection between empirical observations and conceptual insights.

3 RESULTS – CASE STUDY

The relationship between Cassey Ho and POPFLEX serves as an excellent example of how a brand can emerge from a robust personal brand. This case also highlights the pivotal role of content marketing in fostering community engagement. By inspiring consumer trust, content marketing paves the way for the formation of parasocial relationships, which in turn enhance consumers' willingness to make purchases. The case study illustrates the impact of parasocial relationships on a brand. Cassey Ho has successfully built a strong brand with the support of her community. Furthermore, this case study underscores how customer centricity bolsters consumer loyalty.

Cassey Ho is an American fitness trainer, content creator, and founder of the POPFLEX brand. She discovered Pilates during university and became an instructor, forming a close community among her students. After graduating, she launched her Blogilates blog in 2009 and uploaded videos to YouTube to stay connected with them. Her videos gained worldwide popularity, making her an internet celebrity, though her goal was simply teaching Pilates. During college, she designed a functional and aesthetically pleasing bag that became popular among students. After her bag appeared in Shape magazine in 2010, she left her job to become a full-time Pilates instructor (Truong 2022).

Cassey continuously uploaded YouTube videos while building her community, appearing on platforms like Facebook, Twitter, Instagram, and TikTok (Hickey 2021). Social platforms help foster audience engagement and build brand loyalty (Zheng et al. 2015). Through effective social media use, her followers became enthusiastic fans who worked out with her, creating a deeper connection. When followers requested her own t-shirts, Cassey realized Blogilates had evolved into a brand. The Blogilates T-shirts sold out within minutes, and due to their popularity, several companies began copying the design. Cassey Ho decided she needed to build a real brand; she no longer wanted to just sell Blogilates merch T-shirts, so she founded POPFLEX. Today, POPFLEX has become a company with its own product development team and is seeking new people due to growing workload. The emergence of POPFLEX illustrates how customer centric businesses can evolve directly from online communities. Rather than identifying a market segment first and then attracting customers, the brand developed in response to needs already expressed by an existing audience, reflecting the customer centric principle of organizing business activities around customer needs.

POPFLEX is an inclusive Body Positivity brand, offering functional sportswear and accessories in sizes XXS to XXXL. Cassey Ho involves her audience in product design. She uploads videos of the design process to social media, asking for feedback and assessing demand for products. If the community requests a specific product, they design that as well. Previously, Cassey asked followers to vote on T-shirt slogans (Shan 2022). This shows how important the community is to Cassey; she offers solutions tailored to their needs. Her constant feedback from customers and quick response to their needs increases the brand's popularity. Every product is tested on multiple body types to ensure proper fit. This practice demonstrates customer co-creation and responsiveness to customer needs. By incorporating audience feedback into product development, POPFLEX moves beyond traditional product-centric decision making and adopts a more collaborative approach to value creation.

As Cassey's following grew, brands approached her with collaboration offers. However, these brands would dictate what she could do during partnerships. Not wanting others to control her, Cassey focused on her own brand, Blogilates. She founded her activewear brand, POPFLEX, which addressed issues other brands' products failed to solve. These problems connected Cassey with her community, such as workout leggings that are not see-through and "camel toe" free. In 2015, Cassey shared the "Perfect Body" video drawing attention to online bullying and standing up for body positivity (Walravens 2016). The video went viral, and Cassey became identified with the body positivity movement. Her brand was built accordingly. POPFLEX launched in 2016, emphasizing functionality and ensuring wearers felt good while working out, regardless of body shape or size. The alignment between the body positivity movement and the brand's product strategy highlights the role of shared values in customer centric communication. By addressing concerns already present within the community, the brand strengthened identification and trust among followers.

Cassey evolved alongside her brand, designing products that matched her current lifestyle. When she no longer enjoyed wearing Blogilates-branded T-shirts, she stopped selling them, despite their success. She doesn't follow trends, relying on intuition, so while POPFLEX adapts to trends, it remains authentic to its values. Cassey Ho, Blogilates, and POPFLEX are now almost synonymous. While viewers once discovered Cassey through fitness videos, product showcase and design videos now attract the largest audiences. These elements continue to evolve together, and POPFLEX has grown its revenue for years.

Cassey was primarily present online as a trainer, uploading Pilates videos and sharing challenges and workout calendars on her blog. As one of YouTube's first celebrities, she built a community and grew her viewership. When the market became saturated with fitness influencers, Blogilates was already a leading channel with a huge following. Initially, POPFLEX focused on creating instructional videos. However, Cassey felt she had shown everything in this area, reflected in her viewership numbers. Her focus shifted to showcasing product design processes. Several videos went viral. She uploads primarily to YouTube Shorts, TikTok and Instagram. Through short videos, she reached more people. Her fitness videos remain available for new followers. This shift demonstrates the adaptive nature of customer centric communication. Rather than remaining committed to a single content format, Cassey adjusted her communication strategy in response to changing audience preferences and platform dynamics.

Cassey recognized when to change both style and content. Her style aligns with prevailing trends while remaining authentic, as designs stem from her ideas rather than market forecasts. She doesn't consciously follow trends – as different eras emerge, Cassey evolves with them, allowing designs to renew. Each transition happens smoothly and imperceptibly, as change is an ongoing process rather than a single moment. Her collections include both smaller (e.g., cottagecore) and larger trends (e.g., minimalism), but only those Cassey truly identifies with, ensuring brand authenticity. She has created a collection inspired by the Bridgerton series.

Videos uploaded by Cassey to Blogilates bring the most traffic to POPFLEX, but they are exploring other marketing tools. Cassey maintains authenticity in marketing; user-uploaded TikTok videos help promote the brand organically, not as paid content (Shan 2022). She is active on social media, establishing presence on new platforms with authentic content tailored to each platform's users (Yahoo Finance 2022).

Cassey primarily uses content marketing, including her videos, customer-created content, and social media posts. Content marketing provides solutions to current problems (Hajdú 2022). Consumers increasingly avoid advertisements but find content marketing more trustworthy. It helps build product-focused communities that can become content creators, increasing brand trust (Du Plessis 2017). Cassey leverages this organic content, which reaches more people and proves more effective than paid ads. Content marketing's advantage lies in consumers not perceiving it as advertising. Content marketing enables consumer conversations, showing the brand values feedback (Du Plessis 2017). Cassey Ho consistently responds to viewer feedback (Yahoo Finance 2022). Her product videos boost viewership and sales. Consumer trust can develop into parasocial relationships. Through storytelling, Cassey shares her personal journey, connecting with followers. To improve brand experience, companies use touchpoints - activities connecting company to consumer (Calabretta et al. 2019). Content marketing serves as a touchpoint, guiding consumers through the customer journey and purchase funnel stages.

YouTube is a direct platform that can lead to parasocial relationships, as people uploading videos share their lives with followers. Viewers are often referred to as friends. Cassey Ho shares her life with followers and considers viewers as friends (Roth 2020; WeWork 2018). The more authentic someone is and the more personal information they share, the more likely parasocial relationships will develop in viewers (Ferchaud et al. 2018). In fitness channels, working out creates the impression that viewers are exercising alongside the video creator. Parasocial relationships form on both individual and group levels (Jarzyna 2021). Blogilates fans call themselves POPsters. Consumers become curious, bonds develop, and subscribers receive notifications about new videos to watch content early. In comments, viewers interact with each other, and creators sometimes reply, strengthening the illusion of real relationships. The case suggests that customer centric engagement practices may simultaneously facilitate parasocial relationship formation. Frequent interaction, self-disclosure, and community participation create conditions in which followers perceive a stronger personal connection to both the influencer and the associated brand.

Cassey had an online community before the Covid-19 quarantine period. Blogilates gained popularity during the pandemic (Hickey 2021). Lockdowns and lack of human connections increased people's need for parasocial relationships (Jarzyna 2021). During and after this period, POPFLEX increased revenues, partly due to parasocial relationships. The more viewers like content creators, the more easily YouTube addiction develops (de Bérail et al. 2019). YouTube addiction increases time spent consuming content, facilitating parasocial relationships. These relationships with creators also increase consumers' willingness to purchase (Ashraf et al. 2023). Based on the case study, Table 1. summarizes the themes occurring during the analysis of the reviewed material.

Table 1: Themes in the case study and their relevance to literature

Theme	Evidence from Case Study	Relation to Literature
Co-creation	Followers vote on product features	Customer centricity
Responsiveness to Customer Feedback	Inclusion of audience comments and requests to product development	Customer centricity
Community Engagement	Social media interactions	Relationship marketing
Authenticity	Transparent processes	Influencer marketing
Transparent and Engaging Social Media Content	Frequent and continuous posting on social media	Content marketing
Parasocial Relationship	Followers identify as POPsters	Parasocial theory
Customer Loyalty	Followers repeatedly engage with the content	Parasocial theory

(Source: Author's own construction based on the case study)

4 DISCUSSION

Cassey Ho has come a long way, from designing her first bag to her current successful brand. She owes her success to several factors: her personal brand and her clothing brand complement each other, their fit is excellent, which makes it easy for her to reach her target audience. Her professional expertise, creativity, and individuality hold together the community that has formed around Cassey, Blogilates, and POPFLEX. Cassey's story is inspiring, and it demonstrates how someone can go from influencer to entrepreneur and business owner, all while maintaining her original purpose and staying true to herself. It also clearly illustrates how a customer centric approach can make a business successful.

Cassey Ho is an authentic person who produces excellent content, engages her audience, and turns them into a community. She has recognized that different platforms require different kinds of content and styles to reach people, yet her core message remains the same everywhere. The brands of Cassey Ho, Blogilates, and POPFLEX are such a perfect match that they have now blended into one another. This can be a huge advantage from a branding perspective. However, it is important to mention what customer centricity means in her case. If she changes her content too much based on follower feedback, she risks losing the authenticity that makes her so appealing to many people. Therefore, for her, it makes more sense to focus only on those consumers who form her core follower and customer base, whose needs she can truly serve. Among the principles of customer centricity is also the idea that those customers whom the company cannot, or should not, serve, must be let go.

There is a fine line between feedback that helps improve a product and situations where (potential) buyers completely reshape every plan. Although it is important to pay attention to feedback, control should never be handed over to the audience entirely. She created the POPFLEX brand to have freedom, so that no other brands could dictate what she can and cannot do; however, it's no better if consumers do the same. Cassey must find the golden mean with her collections and let go of follower feedback that does not stay true to her authenticity.

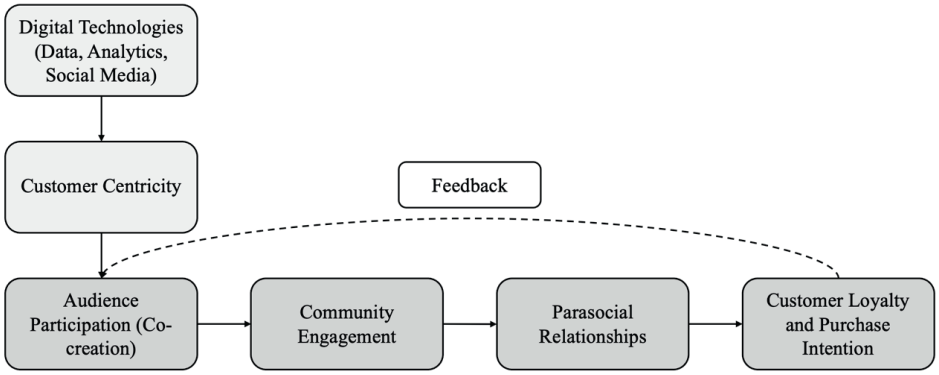
Her example shows us that customer centricity does not mean customers have all the control – instead, it means that the company serves those consumers who identify with the company's and brand's values as well as possible. Figure 1. presents the conceptual framework developed from the literature review and the findings of the case study. The framework suggests that digital technologies and social media platforms create the conditions necessary for customer centric practices by enabling continuous interaction between brands, influencers, and audiences. Through mechanisms such as audience feedback, participation in product development, and ongoing communication, customer centricity becomes operationalized in the digital environment.

Customer centric practices foster community engagement by encouraging followers to actively participate in brand-related activities and discussions. As followers become increasingly involved, they develop a stronger sense of belonging to the community surrounding both the influencer and the brand. This engagement contributes to the formation of parasocial relationships, characterized by trust, emotional attachment, and perceived closeness between followers and the influencer.

The framework further proposes that parasocial relationships strengthen customer loyalty and brand support, increasing the likelihood of continued engagement, advocacy, and purchasing behavior. However, the process is not strictly linear. Loyal and highly engaged followers continue to provide feedback through comments, interactions, and product suggestions. This feedback supplies valuable information about audience preferences and expectations, allowing influencers and brands to refine products, content, and communication strategies. Consequently, customer centricity functions as a continuous feedback-driven cycle in which engagement and relationships generate insights that support future customer centric decisions.

The case of Cassey Ho and POPFLEX illustrates this process particularly well. Through the ongoing incorporation of follower feedback into content creation and product development, customer centricity, community engagement, parasocial relationships, and brand loyalty reinforce one another in a dynamic and mutually strengthening system.

Figure 1: How customer centricity can lead to increased purchase intention through community building and parasocial relationships



(Source: Author's own visualization)

5 CONCLUSION

This paper examined how customer centricity has evolved in the digital age, with particular emphasis on the role of data-driven tools, real-time analytics, and influencer-led engagement. Building on the customer centricity literature, the study highlighted how digitalization has expanded traditional customer centric approaches by enabling personalization, hyper-personalization, and continuous interaction between companies and consumers. These developments allow organizations not only to better understand customer needs but also to actively involve customers in value creation processes.

The case study of Cassey Ho and the POPFLEX brand illustrated how customer centricity can be effectively operationalized in a digital and influencer-driven context. The findings show that involving followers in product development, responding to feedback, and maintaining authentic communication can strengthen customer engagement and loyalty. At the same time, these practices contribute to the formation of parasocial relationships, which further enhance consumers' emotional attachment to both the influencer and the brand. The case demonstrates that customer centricity is not limited to firm-level strategies but can also be successfully applied by brand-owning influencers who simultaneously act as content creators, community leaders, and entrepreneurs.

Importantly, the findings also underline that customer centricity does not imply relinquishing strategic control to consumers. Instead, successful customer centric strategies require a careful balance between listening to customer feedback and preserving brand authenticity and core values. Serving a clearly defined group of customers whose needs align with the brand's identity appears to be more effective than attempting to satisfy all audience demands.

This study contributes to the literature by linking data-driven customer centricity with influencer marketing and parasocial relationships, offering insights into how these concepts intersect in practice. However, the paper is limited by its single-case-study design, which restricts the generalizability of the findings. Future research could address this limitation by examining multiple influencers or brands across different industries, or by employing quantitative methods to test the relationships between customer centricity, parasocial interaction, and consumer outcomes. Such research could further deepen understanding of customer centricity as a strategic resource in increasingly digital and community-driven markets.

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1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

TRUST AND TECHNOLOGY ACCEPTANCE IN DIGITAL HEALTH COMMUNICATION: INTEGRATING THE IDEA-COMMTRUST MODEL WITH TAM AND UTAUT

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ABSTRACT

The adoption of digital health technologies depends not only on technical functionality, but also on the quality of communication through which healthcare institutions explain, justify, and support their use. Established technology acceptance models, particularly the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), explain adoption mainly through cognitive evaluations such as perceived usefulness, ease of use, performance expectancy, social influence, and facilitating conditions. In healthcare, these determinants are closely linked to trust, perceived risk, data security, and institutional accountability. This paper presents a conceptual review and theoretical synthesis of literature on technology acceptance, trust, and digital health communication. Its aim is to integrate the IDEA-CommTrust communication framework with TAM and UTAUT in order to clarify how communication practices contribute to trust formation and how trust subsequently shapes technology acceptance. The proposed framework conceptualizes communication through four dimensions: information, dialogue, empathy, and institutional accountability. The synthesis suggests that trust should not be treated only as an additional variable in extended acceptance models, but as a relational construct formed through identifiable communication practices. Transparent information may reduce perceived risk and strengthen perceived usefulness; dialogue and user support may reinforce facilitating conditions; empathetic communication may reduce uncertainty and resistance; and institutional accountability may increase perceptions of legitimacy and security. Within the proposed model, trust functions primarily as a mediator between communication and behavioral intention, while also potentially moderating the effects of perceived risk and social influence. The framework offers a communication-sensitive extension of technology acceptance theory in digital healthcare and provides a basis for future empirical testing using structural equation modelling and comparative studies across user groups and digital health settings.

Keywords: *digital health, trust, technology acceptance, health communication, institutional accountability*

1 INTRODUCTION

The digital transformation of healthcare has accelerated the development of telemedicine services, mobile health applications, and electronic health records, with the aim of improving the quality of care and the efficiency of healthcare systems. Despite the demonstrated benefits of numerous digital health solutions, their long-term implementation is often limited by insufficient acceptance among end users (Catapan et al. 2025). Understanding the factors that influence the adoption of digital technologies has therefore become a central research question in contemporary health informatics and health communication research.

Among the most widely used theoretical frameworks for explaining technology adoption are the Technology Acceptance Model (TAM) (Davis 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003). TAM identifies perceived usefulness and perceived ease of use as the primary determinants of behavioral intention to use technology (Davis 1989, 320). UTAUT expands this analytical framework by incorporating additional constructs, including social influence, facilitating conditions, and moderating variables such as age, gender, experience, and voluntariness of use (Venkatesh et al. 2003). Empirical applications of these models in healthcare contexts have confirmed their relevance for explaining the adoption of information systems, while also highlighting the need for further conceptual adaptation to the specific characteristics of healthcare environments (Holden and Karsh 2010; AlQudah et al. 2021).

In healthcare settings, decisions about the use of digital systems are not determined solely by the evaluation of their technical functionality. They are also strongly influenced by the level of trust users place in both the technology itself and the institutions responsible for its implementation. Trust has long been recognized as a fundamental component of the patient–healthcare professional relationship and a prerequisite for the effective functioning of healthcare systems (Mayer et al. 1995; Adjekum et al. 2018). In digital environments, however, concerns regarding data security, algorithmic reliability, and institutional accountability may reduce users' willingness to adopt technological solutions, even when their functional benefits are acknowledged (Bansal et al. 2010; Catapan et al. 2025).

Experiences during the COVID-19 pandemic further highlighted the close relationship between communication practices and public trust in digital health technologies. In conditions characterized by heightened uncertainty, the public did not evaluate digital tools solely on the basis of their technical functionality, but also on how institutions communicated their purpose, limitations, and associated risks. Transparent, timely, and contextualized communication proved essential for shaping perceptions of security, legitimacy, and institutional credibility (Adjekum et al. 2018; Kuen et al. 2023).

Building on these insights, this paper proposes an integrated conceptual framework in which communication practices contribute to the development of trust, while trust mediates the relationship between communication and key determinants of technology acceptance. By connecting communication theory with established models of technology adoption, the study aims to provide a broader understanding of how digital health technologies are perceived and adopted within complex socio-technical healthcare environments.

2 PURPOSE AND GOALS

The purpose of this review paper is to theoretically examine the relationship between communication practices, trust, and the acceptance of digital technologies in healthcare. The analysis is based on the assumption that communication shapes the level of users' trust in digital health systems, while trust subsequently mediates the relationship between communication and key determinants of technology acceptance. Within this framework, the paper connects the IDEA-CommTrust communication model with the established technology acceptance models TAM and UTAUT.

The main objectives of the study are:

1. To analyse the core constructs of the TAM and UTAUT models in the context of digital healthcare, including their empirical application and the limitations identified in previous research.
2. To examine the role of trust as a relevant construct in technology acceptance models, drawing on literature that integrates trust, perceived risk, and behavioral intention to use digital health technologies.

3. To systematize key communication dimensions—transparency, dialogue, empathy, and institutional accountability—as essential preconditions for building trust in digital healthcare environments.
4. To propose an integrated conceptual framework in which communication practices influence trust, while trust subsequently affects the principal determinants of technology acceptance, thereby extending the analytical scope of existing technology acceptance models.

The central research question addressed in this paper is: How do communication practices of digital health service providers influence user trust, and how does this trust shape perceived usefulness, perceived ease of use, and the intention to use digital technologies?

The response to this question is developed through a conceptual synthesis of relevant literature and the formulation of an integrated theoretical model linking communication processes, trust, and technology acceptance.

3 METHODS

This paper is designed as a narrative theoretical review of the literature aimed at the conceptual integration of existing models and empirical findings. No original empirical research was conducted; instead, the analysis is based on a structured review and interpretative synthesis of relevant scientific sources.

The literature search was conducted in the Scopus and Web of Science databases, with additional screening of relevant publications through Google Scholar. The following search terms and their combinations were used: *digital health*, *technology acceptance*, *TAM*, *UTAUT*, *trust*, *communication*, *e-health*, and *mHealth*. The review primarily included studies published between 2010 and 2025, while also incorporating foundational theoretical works that established the TAM and UTAUT models and the theoretical foundations of organizational and technological trust.

The inclusion criteria for the literature were as follows:

a) studies analysing technology acceptance models in healthcare contexts;
b) research examining the role of trust in e-health systems or other technology-mediated environments characterized by high perceived risk;
c) publications addressing communication strategies relevant to the development of trust in digital environments;
d) theoretical and review papers enabling the conceptual integration of technology acceptance, trust, and communication research.

Studies focusing exclusively on the technical implementation of digital systems without consideration of user perception or behavioral factors were excluded. Likewise, publications outside the healthcare context that did not provide relevant theoretical implications for digital health adoption were not included.

The literature was analysed through thematic synthesis. Three primary analytical domains were identified: (1) determinants of technology acceptance within the TAM and UTAUT models, (2) the role of trust and perceived risk in digital healthcare environments, and (3) communication factors influencing the development of trust in digital technologies. Based on a comparative analysis of these domains, a conceptual framework was developed that integrates communication dimensions with the construct of trust and established technology acceptance models.

The proposed model was formulated using a deductive approach, drawing on established theoretical constructs and relationships described in previous research. Consequently, the outcome of this study represents a conceptual integration rather than an empirical validation of the proposed framework.

In addition to academic literature, official documents from international and national institutions relevant to digital health were consulted in order to confirm the contemporary relevance of the research problem.

Since this study is a conceptual review based on published literature and publicly available institutional documents, no empirical data were collected and no human participants were involved. Ethical approval was therefore not required. The analytical outcome of the review is presented as a conceptual synthesis rather than as empirical results. The findings are formulated as theoretical

propositions derived from the comparative interpretation of technology acceptance models, trust research, and communication theory.

4 THEORETICAL BACKGROUND: COMMUNICATION, TRUST, AND TECHNOLOGY ACCEPTANCE

4.1 Technology Acceptance Models (TAM and UTAUT) in Healthcare

The Technology Acceptance Model (TAM) was developed by Davis in the late 1980s as a theoretical framework for explaining users' intentions to adopt information systems (Davis 1989). According to TAM, two fundamental cognitive evaluations shape attitudes toward technology and, consequently, behavioral intention to use it: perceived usefulness, defined as the belief that the use of a system will enhance work or health-related outcomes, and perceived ease of use, referring to the extent to which a user expects a system to be free of effort. Empirical studies conducted in both general information technology contexts and healthcare environments have confirmed the stability of these constructs and their strong association with the intention to use technological systems (Holden and Karsh 2010; AlQudah et al. 2021).

Within the domain of healthcare technologies—including electronic health records, clinical decision-support systems, and telemedicine platforms—the TAM constructs have demonstrated the capacity to explain a significant proportion of variance in technology adoption among both healthcare professionals and patients (Holden and Karsh 2010). Nevertheless, the model has also been criticized for its limited consideration of broader social and organizational factors influencing technology adoption.

As an extension of the original model, TAM2 was developed to incorporate additional determinants such as subjective norms, job relevance, and output quality, as well as the moderating role of user experience (Venkatesh and Davis 2000). In the early stages of technology implementation, social influence may play a particularly important role, especially in hierarchically structured environments such as healthcare systems.

The Unified Theory of Acceptance and Use of Technology (UTAUT) integrates elements from several earlier theoretical models and identifies four key predictors of behavioral intention and technology use: performance expectancy (conceptually equivalent to perceived usefulness), effort expectancy (related to perceived ease of use), social influence, and facilitating conditions (Venkatesh et al. 2003). The model also includes moderating variables—such as age, gender, experience, and voluntariness of use—that may influence the strength of relationships among the constructs. In healthcare settings, performance expectancy frequently emerges as the strongest predictor of behavioral intention, while the relative importance of other determinants depends on the specific organizational and clinical context (Philippi et al. 2021).

Despite their strong empirical support, both TAM and UTAUT were originally developed outside the healthcare domain and primarily assume a rational decision-making process based on the evaluation of expected benefits and required effort. In healthcare environments, however, technology adoption is also influenced by additional considerations, including data security, professional responsibility, ethical implications, and trust in the institutions responsible for implementing digital systems. These aspects are not explicitly incorporated into the basic versions of TAM and UTAUT (Holden and Karsh 2010).

For this reason, several scholars have extended these models by introducing additional constructs, among which trust has emerged as particularly significant. In the context of electronic commerce, Gefen et al. (2003) demonstrated that trust can have a direct effect on behavioral intention to use technology, independent of perceived usefulness. Similar theoretical integrations have been proposed in healthcare research, where trust in both the technology and the service provider is considered an important determinant of technology acceptance (Ortega Egea and Román González 2011; Schnall et al. 2015; Hoque and Sorwar 2017).

The following section therefore focuses on the concept of trust in digital healthcare and its conceptual role in relation to technology acceptance models.

4.2 The Role of Trust in Digital Healthcare

In the literature, trust is most commonly defined as the willingness of one party to accept vulnerability in relation to another, based on the expectation that the other party will act competently, benevolently, and responsibly (Mayer et al. 1995). In traditional healthcare settings, trust is primarily associated with the relationship between patients and healthcare professionals, encompassing beliefs in professional competence, ethical conduct, and commitment to the patient's well-being. In digital healthcare environments, however, the object of trust expands beyond interpersonal relationships to include the technologies themselves and the institutions responsible for their development and implementation.

Trust in digital health systems involves users' evaluations of functional reliability, data security, accuracy of information, and the institutional accountability of service providers (Adjekum et al. 2018). Empirical studies indicate that trust represents a multidimensional construct associated with perceived risk, privacy concerns, information quality, and user experience. A systematic review by Catapan et al. (2025) demonstrates that trust significantly influences the intention to use digital health services and may also affect users' perceptions of technological usefulness.

Further research suggests that different objects of trust may coexist in digital healthcare environments. Kuen et al. (2023), for example, distinguish between trust in physicians, trust in technology, and trust in the treatment process. Their findings indicate that in telemedicine contexts, trust in the technological platform itself may exert a stronger influence on usage intention than interpersonal trust in the physician. Such results highlight the importance of considering technological trust as a distinct construct within models of technology acceptance.

The integration of trust into technology acceptance models has been examined in various contexts. In the domain of electronic commerce, Gefen et al. (2003) demonstrated that trust can have a direct effect on behavioral intention to use technology, independent of perceived usefulness. In healthcare research, Ortega Egea and Román González (2011) incorporated trust and perceived risk into an extended TAM model and found that trust mediates the relationship between perceived risk and physicians' intention to use electronic health record systems. These findings suggest that reducing perceived risk and strengthening trust represent key mechanisms for increasing technology acceptance.

Similar patterns have been identified in the context of mobile health applications. Distrust related to data accuracy, privacy protection, or the transparency of algorithms has been associated with a reduced intention to continue using health-monitoring applications, even when users recognize their functional value (Adjekum et al. 2018; Catapan et al. 2025). Consequently, the literature emphasizes mechanisms such as transparent privacy policies, regulatory certification, and user control over personal data as important factors contributing to the development of trust in digital health systems.

Overall, trust in digital healthcare can be understood as a mediating construct linking perceptions of risk, quality, and institutional legitimacy with the intention to use technological solutions. The following section therefore examines the communication dimension of this process and explores how communication practices may shape the level of trust users place in digital health technologies.

4.3 Communication as a Foundation of Trust: The IDEA-CommTrust Model

The acceptance of digital health technologies depends not only on their technical characteristics but also on how these technologies are presented, explained, and contextualized to users. Communication processes accompanying the introduction and use of digital systems shape users' perceptions of their security, legitimacy, and reliability.

The IDEA-CommTrust model was developed as an extension of the original IDEA model of risk and crisis communication (Internalization, Distribution, Explanation, Action) (Sellnow et al. 2017), introducing trust as an integrative and evaluative dimension of the communication process (Petričević 2024). In this paper, the model is conceptually adapted to the context of digital healthcare. Communication dimensions are operationalized through four interrelated components: information, dialogue, empathy, and accountability. These dimensions represent communication mechanisms through which trust in digital health systems can be shaped.

Information. Transparent, timely, and comprehensible communication about system functionality, data processing, and potential risks represents a fundamental prerequisite for building trust. In healthcare contexts, this includes explaining the purpose of data collection, security mechanisms, and the expected benefits for users. A lack of clear information or the use of technical jargon may increase perceived risk and reduce users' willingness to adopt technological solutions (Adjekum et al. 2018; Maina and Singh 2022).

Dialogue. Two-way communication allows users to express concerns and ask questions, thereby reducing information asymmetry between institutions and users. The introduction of feedback mechanisms—such as pilot programmes, user surveys, or support channels—can strengthen perceptions of user inclusion and the legitimacy of digital systems (Vayena et al. 2018; Adjekum et al. 2018). Dialogue in this context does not merely represent technical assistance but also signals institutional openness and responsiveness.

Empathy. Digital health services are frequently used in situations characterized by uncertainty, vulnerability, or emotional stress. Communication that acknowledges these circumstances and employs clear, accessible, and considerate language contributes to users' sense of security. Trust in digital systems therefore arises not only from technical reliability but also from the perception that competent and responsible professionals stand behind the technology (World Health Organization 2021; Montague and Asan 2012; Lupton 2014).

Accountability. Institutional credibility and the willingness to assume responsibility for the functioning of digital systems represent an important source of trust. This includes transparent responses to potential errors, adherence to regulatory and ethical standards, and consistent communication regarding privacy and data security policies. Institutional reputation and formal oversight mechanisms can further reinforce perceptions of reliability and legitimacy (Maina and Singh 2022; Adjekum et al. 2018).

Within this framework, the IDEA-CommTrust model does not treat communication as a secondary element of technology implementation, but rather as a structural component of the technology acceptance process. The systematic application of these communication dimensions contributes to the development of trust, which may subsequently influence perceived usefulness, perceived ease of use, perceived risk, and the behavioral intention to use digital technologies.

Digital health services can therefore be understood as socio-technical systems in which technological functionality and communication practices are inseparably linked. Alignment of communication strategies with the principles of transparency, dialogue, empathy, and accountability increases the likelihood that users will perceive digital technologies as legitimate and trustworthy, thereby creating a crucial precondition for their successful adoption.

5 RESULTS: CONCEPTUAL SYNTHESIS AND INTEGRATED FRAMEWORK

As this paper is conceptual in nature, the results are not presented as empirical findings but as outcomes of theoretical synthesis. The synthesis identifies the main relationships between communication practices, trust formation, and technology acceptance constructs, and formulates an integrated framework linking IDEA-CommTrust with TAM and UTAUT (Table 1).

Table 1: Comparison of TAM, UTAUT, trust-extended acceptance models, and the proposed IDEA-CommTrust integration

Model / framework	Core constructs	Treatment of trust	Main limitation in digital health	Contribution of the proposed framework
TAM	Perceived usefulness, perceived ease of use, behavioral intention	Trust is not included in the original model.	Limited attention to institutional trust, perceived risk, data security, and communication practices.	Communication explains how trust may shape perceived usefulness, perceived ease of use, and behavioral intention.

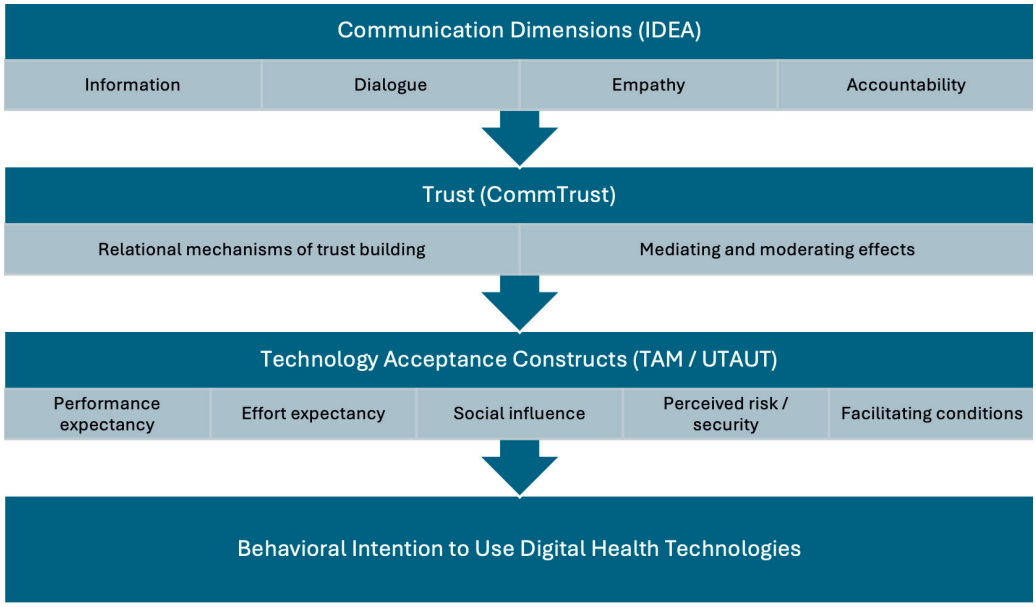
UTAUT	Performance expectancy, effort expectancy, social influence, facilitating conditions	Trust is not included as a central construct.	The model considers social and organizational conditions, but does not explain how institutional trust is formed.	Dialogue, user support, and accountability clarify how facilitating conditions and social influence gain credibility in healthcare settings.
Trust-extended TAM/UTAUT models	Trust, perceived risk, privacy concerns, behavioral intention	Trust is usually treated as an additional predictor, mediator, or moderator.	These models often examine the effects of trust without explaining its communicative origins.	IDEA-CommTrust specifies the communication mechanisms through which trust is formed.
IDEA-CommTrust–TAM/UTAUT	Information, dialogue, empathy, accountability, trust, and TAM/UTAUT acceptance constructs	Trust is conceptualized as both an outcome of communication and a mediator or moderator of technology acceptance.	The proposed relationships require empirical validation across different digital health settings and user groups.	The framework integrates communication theory with technology acceptance theory and explains how institutional communication contributes to digital health adoption.

(Source: Authors' own work)

The originality of the proposed framework lies in its treatment of trust not merely as an additional variable within technology acceptance models, but as a relational construct emerging from identifiable communication practices. Previous trust-extended TAM and UTAUT models usually incorporate trust as a predictor, mediator, or moderator of behavioral intention. The IDEA-CommTrust integration extends this logic by specifying the communicative mechanisms through which trust is formed: information, dialogue, empathy, and institutional accountability. In this sense, the model shifts analytical attention from the effects of trust to the conditions under which trust is communicatively produced in digital health environments.

Based on the theoretical considerations discussed above, communication factors, trust, and technology acceptance models can be integrated into a single conceptual framework. The central assumption is that communication practices structured according to the principles of the IDEA-CommTrust model contribute to the development of users' trust in digital health solutions, while trust subsequently functions as a key theoretical link between communication processes and the determinants of technology acceptance (Figure 1).

Figure 1: Integrated conceptual framework of the IDEA–CommTrust–TAM/UTAUT model



(Source: Authors' own visualisation)

Within the proposed framework, trust primarily plays a mediating role between communication dimensions (information, dialogue, empathy, and accountability) and the intention to use technology. At the same time, in certain relationships—particularly those involving perceived risk and behavioral intention, as well as social influence and behavioral intention—trust may also function as a moderating variable, strengthening or weakening the intensity of these relationships. In this way, trust is conceptualized as a dynamic construct that both transmits the effects of communication and modifies the impact of selected cognitive evaluations.

Communication interventions may contribute to shaping key constructs within the TAM and UTAUT models. Transparent and timely information regarding the purpose, functionality, and security mechanisms of digital systems may increase perceived usefulness while simultaneously reducing perceived technological complexity. Establishing dialogue and providing continuous user support can strengthen perceptions of facilitating conditions and user self-efficacy. An empathetic communication approach may reduce technology-related anxiety and resistance to change, whereas the demonstration of institutional accountability can mitigate perceived risk. Through these mechanisms, communication practices contribute to the development of trust, which subsequently influences users' evaluations of usefulness, safety, and institutional legitimacy.

Empirical literature provides support for such integration. Trust has been shown to be a significant predictor of behavioral intention to use technology, independent of perceived usefulness (Gefen et al. 2003). In healthcare contexts, users who perceive digital systems as secure and institutionally credible are more likely to evaluate their outcomes positively. Moreover, trust is associated with lower perceptions of risk and a greater willingness to invest initial effort in learning how to use new technologies (Venkatesh et al. 2012; Gefen et al. 2003). Under conditions of high trust, users are generally more tolerant of initial difficulties and uncertainties, which is particularly relevant in healthcare environments characterized by high stakes and sensitive data.

Trust may also shape the effects of social influence. When institutions and recognized experts publicly endorse specific digital health solutions and are perceived as credible, the social legitimacy of such technologies increases (Maina and Singh 2022; Kuen et al. 2023). In such circumstances, social influence can exert a stronger impact on users' behavioral intentions, particularly among individuals who are initially uncertain about adopting new technological systems.

Figure 1 illustrates the proposed conceptual framework. Communication elements derived from the IDEA model contribute to the development of trust (CommTrust), which then primarily mediates the relationship between communication practices and the intention to adopt digital technologies, while also influencing key TAM/UTAUT constructs—performance expectancy, effort expectancy, social influence, and perceived risk/security. In specific relationships, trust may additionally exert a moderating influence, particularly in the relationships between perceived risk and behavioral intention and between social influence and behavioral intention.

The proposed framework is theoretical in nature and therefore requires empirical validation. Future research could employ structural equation modelling to test the mediating and moderating relationships proposed in the model. Experimental research designs could also be used to examine the effects of different communication interventions on the development of trust and users' intention to adopt digital health technologies. Previous studies in the context of national e-health system implementation indicate that insufficient communication and perceptions of a lack of transparency may contribute to distrust and resistance toward digital systems (Gagnon et al. 2012), while successful implementations are frequently associated with clear guidance, user education, and continuous institutional support (Or and Karsh 2009).

By integrating a communication-based model of trust with TAM and UTAUT frameworks, this study proposes a theoretical bridge between the technological and socio-psychological dimensions of digital health innovation adoption. In this perspective, technology acceptance is not viewed solely as the outcome of cognitive evaluations of usefulness and effort, but also as the result of trust-based relationships between users and the institutions responsible for implementing digital technologies. Such an approach enables a more human-centered and communication-sensitive design of digital healthcare systems.

6 DISCUSSION

The proposed conceptual framework integrates communication processes, trust, and technology acceptance constructs into a unified analytical perspective. This section discusses the theoretical implications of such integration, its relationship to existing technology acceptance models, and its practical relevance for the development and implementation of digital healthcare systems. This approach is relevant not only for theoretical advancement but also for researchers, policymakers, and system designers involved in shaping digital health policies and technological solutions.

6.1 Theoretical Implications

At the theoretical level, the proposed framework contributes to the literature on technology acceptance in healthcare by extending predominantly technical and cognitive models with a communication-based and relational dimension. Models such as TAM and UTAUT have demonstrated strong predictive value in explaining users' intentions to adopt technological systems. However, numerous scholars have emphasized their limitations when applied to contexts characterized by high levels of risk, ethical considerations, and institutional responsibility, which are inherent to healthcare environments (Holden and Karsh 2010).

The proposed framework does not replace the core constructs of these models but rather expands them conceptually by introducing trust as a central relational mechanism emerging from communication practices. In this perspective, technology acceptance is not interpreted solely as the outcome of cognitive evaluations of usefulness and effort but also as the result of users' perceptions of institutional credibility and legitimacy.

This approach is consistent with findings from systematic reviews indicating that factors such as trust, technology-related anxiety, and perceived risk significantly influence the acceptance of digital health technologies (AlQudah et al. 2021). However, while previous studies often treat trust as an additional predictor within extended acceptance models, the present framework conceptualizes trust as both a mediating variable between communication processes and standard TAM/UTAUT constructs and a moderating factor influencing the relationships between perceived risk, social influence, and behavioral intention.

By integrating the communication dimensions of the IDEA-CommTrust model with established technology acceptance frameworks, a relational component is introduced that clarifies how constructs such as facilitating conditions and social influence may emerge in practice. For example, dialogue and systematic user support contribute to perceptions of institutional accessibility and competence, while transparent communication regarding data protection and security mechanisms may reduce perceived risk. In this sense, communication does not function as an external contextual factor but rather as a processual mechanism through which cognitive evaluations embedded in TAM and UTAUT are formed.

The Theory of Planned Behavior (Ajzen 1991) and related behavioral models have long recognized subjective norms and perceived behavioral control—often linked to information and contextual support—as determinants of human behavior. The proposed conceptual extension places the user at the center of analysis not merely as a rational evaluator of technological characteristics but as an actor whose decisions are shaped within relational and institutional contexts. In this way, technology acceptance models become better adapted to the specific conditions of digital healthcare, where issues of security, accountability, and trust are inseparable from technological functionality.

6.2 Comparison with Previous Research

The proposition that communication practices shape levels of trust and thereby indirectly influence the acceptance of digital health solutions is supported by numerous empirical studies in public health and crisis communication. During the COVID-19 pandemic, research demonstrated that transparent, consistent, and empathetic communication by health institutions increased citizens' willingness to use digital tools—such as contact tracing applications—primarily through the mechanism of strengthening institutional trust (Paakkari and Okan 2020; Fox et al. 2024).

Adjekum et al. (2018), in their review of trust in digital health systems, identify institutional factors—including government involvement, public education campaigns, and the manner in which digital solutions are presented to the public—as key determinants of trust in e-health technologies. Similar conclusions are reported by Maina and Singh (2022), who emphasize the importance of transparency and regulatory accountability. These findings support the inclusion of the communication dimension of accountability within the IDEA-CommTrust framework, where trust is not treated as an abstract attitude but rather as the outcome of concrete institutional communication practices.

Empirical research on extended TAM models further confirms the importance of trust. Studies that incorporate constructs such as trust, perceived risk, and social influence into technology acceptance frameworks report increased explanatory power regarding users' behavioral intention in healthcare contexts (Beldad and Hegner 2018; Adnan et al. 2025). However, within these approaches trust is typically treated as an additional predictor rather than as a construct whose formation is analytically examined.

Particularly relevant is the study by Ortega Egea and Román González (2011), which demonstrated that incorporating trust and perceived risk into an extended TAM framework provided a more comprehensive explanation of physicians' intention to use electronic health record systems. In their model, trust functioned as a mediator between perceived risk and behavioral intention. This finding aligns with the logic of the proposed framework, according to which trust can mitigate the negative effects of perceived risk and strengthen the transition from cognitive evaluation to the decision to adopt technology.

The key distinction between the present framework and previous TAM/UTAUT extensions lies in the emphasis on the communicative origins of trust. Rather than treating trust as an additional variable within an existing structural model, the present approach conceptualizes trust as a relational mechanism emerging from communication practices. Trust subsequently functions as both a mediating and moderating factor within the technology acceptance process. In this way, insights from crisis and health communication research are integrated with technology acceptance theories into a coherent analytical framework.

6.3 Practical Implications

The proposed framework has relevant implications for the planning and implementation of digital health solutions. Integrating communication dimensions into the technology acceptance process suggests that communication should be considered an integral component of implementation strategies rather than a secondary or subsequent activity. The introduction of new digital systems therefore requires not only technical adaptation of infrastructure but also structured communication interventions directed toward users.

Such interventions may include the development of educational materials, the organization of training sessions and public information events, transparent communication regarding data security and privacy protocols, and the establishment of mechanisms for continuous user feedback. Involving professional authorities or users with positive prior experience may further strengthen the perceived legitimacy of the system through processes of social validation. In this sense, communication activities can be understood as investments in institutional trust capital, which indirectly influences the success of technological implementation.

Examples from international practice illustrate the importance of such an approach. Estonia has developed an integrated national e-health system that includes electronic health records, e-prescriptions, and a patient portal. The system was accompanied by a clear communication strategy and strong institutional support, contributing to a high level of public acceptance (European Commission 2019). In contrast, studies examining the implementation of electronic health records in Canada indicate that insufficient involvement of healthcare professionals and limited communication regarding the value of the system may represent significant barriers to adoption (McGinn et al. 2012).

At the level of individual applications or digital platforms, communication elements may also be integrated directly into the user experience. Transparent privacy labels, clear explanations of data processing procedures, accessible support channels, and visible connections with professional teams responsible for system oversight may strengthen perceptions of safety and institutional le-

gitimacy. Such elements should not be regarded merely as aesthetic or functional additions but as mechanisms for building trust that indirectly shape users' willingness to engage with digital technologies over the long term.

6.4 Limitations and Directions for Future Research

Although the proposed framework is conceptually grounded in relevant literature, its empirical validation represents the next necessary step. Future research should operationalize the communication dimensions of the IDEA-CommTrust model and examine their relationships with trust and the core constructs of technology acceptance. The development and validation of measurement instruments capturing perceived transparency of information, quality of dialogue, perceived empathy in communication, and perceptions of institutional accountability would enable empirical testing of the model using structural equation modelling (SEM), including analyses of mediating and moderating effects.

Longitudinal research designs could further contribute to understanding the dynamics of trust, particularly during the stages from the initial announcement of a technology to its full implementation. Such an approach would allow researchers to monitor changes in user perceptions over time and identify critical phases in which communication interventions have the greatest impact.

One potential limitation concerns the heterogeneity of user groups. Perceptions of communication and the formation of trust may differ depending on age, digital literacy, or professional role. Older users may place greater emphasis on direct human support, whereas healthcare professionals may base trust primarily on scientific evidence, professional guidelines, and the integration of digital systems into existing clinical workflows. Future research should therefore examine the applicability of the framework across different populations and determine whether contextual adaptations are required.

Furthermore, the model assumes that communication contributes positively to the development of trust, yet it is equally important to consider its potential negative effects. Ambiguous, inconsistent, or contradictory communication may undermine trust even in technically reliable systems. Empirical research could identify potential thresholds or "critical points" at which trust begins to deteriorate and examine the role of crisis communication strategies in restoring institutional credibility.

Finally, trust in digital health systems should not be considered a static construct. Its sustainability depends on the consistency between communicated messages and the actual performance of technological systems. Technical failures, security incidents, or unmet expectations may produce feedback effects that alter users' perceptions over time. Future studies should therefore explore the bidirectional relationship between system performance, communication interventions, and the long-term maintenance of trust in digital healthcare environments.

7 CONCLUSION

The main theoretical contribution of the proposed framework is that it explains the communicative formation of trust, rather than treating trust only as an additional determinant of technology acceptance. This paper examined the relationship between communication, trust, and technology acceptance within the context of digital healthcare and proposed an integrative conceptual framework connecting the IDEA-CommTrust model with the core constructs of TAM and UTAUT. The analysis was based on the premise that traditional technology acceptance models, although empirically validated, do not sufficiently capture the relational and institutional dimensions of trust that are particularly pronounced in healthcare settings.

The theoretical synthesis leads to several key conclusions. First, trust can be conceptualized as a mediator between communication practices and the determinants of technology acceptance. Second, transparent, dialogical, and empathetic communication can reduce perceived risk and indirectly strengthen perceived usefulness and users' behavioral intention to adopt digital technologies. Third, institutional accountability and organizational reputation represent an important contextual framework within which trust in digital systems is formed. Finally, integrating communication and trust dimensions into technology acceptance models enables a deeper understanding of the variability in user behavior observed in digital health environments.

Practical implications arise from the recognition that the implementation of digital health solutions should be viewed as a sociotechnical process. The successful adoption of new technologies depends not only on the technical reliability of systems but also on the quality of communication, the degree of user engagement, and the consistency of institutional actions. A multidisciplinary approach that combines technological expertise with insights from communication and behavioral sciences may contribute to more stable adoption and the long-term maintenance of trust.

Digital healthcare requires the alignment of technological functionality with an appropriate communication architecture. In this context, trust represents a fundamental prerequisite for sustainable technology adoption, particularly in environments characterized by high levels of risk and sensitive data. Since the framework is conceptual, its proposed mediating and moderating relationships require empirical testing across different digital health settings, user populations, and implementation contexts. Despite contextual variations, a central insight remains: technological innovations in healthcare cannot be understood independently of the trust relationships that surround them.

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1.08 Objavljeni znanstveni prispevek na konferenci
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FROM POLITICAL SATIRE TO MORAL UNACCEPTABILITY: A DWORKINIAN ANALYSIS OF MLADINA D.D. LJUBLJANA V. SLOVENIA

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ABSTRACT

The case Mladina d.d. Ljubljana v. Slovenia (No. 2) provides a paradigmatic example of the tension between political satire and the tendency to interpret harsh political expression as morally unacceptable or even comparable to hate speech, revealing a discrepancy between national judicial reasoning and the interpretative approach adopted by the European Court of Human Rights. The paper analyses the case through the lens of Ronald Dworkin's theory of judicial decision-making, as explored in Law's Empire. Methodologically, the paper adopts a normative and interpretative approach, conceptualizing law as a normative phenomenon that actively shapes and responds to social dynamics. The paper argues that judicial sensitivity to allegedly hateful expression is inherently non-neutral: the boundaries between offensive and hateful speech shift depending on the social status of the expression's target, thereby exposing implicit value judgments within judicial reasoning. Through Dworkin's theory of law as integrity, the analysis demonstrates how the case of Mladina v. Slovenia enhances the coherence of European free-speech doctrine by reconciling national adjudication with international human rights standards.

Keywords: *freedom of expression, ECHR, Dworkin, pluralism, satire*

1 INTRODUCTION

Freedom of expression is recognized as one of the cardinal rights within the European Convention on Human Rights, serving as an essential foundation for a democratic society and facilitating the political participation of minorities, opposition groups, and civil society. The historical importance of this right is evident, as it was won and secured through centuries of struggle and reaffirmed as a fundamental value of the Council of Europe after the devastating world wars (Harris et al. 1995, 597).

In contemporary jurisprudence, however, the boundaries of this freedom are constantly tested, particularly in the context of political satire.

Satire inherently employs provocation, exaggeration, and irony to criticize public figures, often exposing the thin boundary between protected speech and alleged defamation or hate speech (Holbert 2013, 306). In controversial cases, courts may interpret harsher forms of satire as morally and socially unacceptable, sometimes treating them as if they belonged to a category of expression comparable to hate speech, even when the legally formal claim primarily concerns defamation.

The research problem focuses on the case Mladina d.d. Ljubljana v. Slovenia (No. 2), which reveals a significant divergence between national judicial reasoning and the interpretative approach of the European Court of Human Rights (ECtHR). The dispute arose from a satirical comparison published in the Mladina column, which compared a photo of the family of Slovenian politician Branko Grims with that of Nazi propaganda minister Joseph Goebbels. Some politicians and even a parliamentary commission deemed the satirical publication hate speech in their public comments (RTV Slovenija 2011).

This case is significant because it illustrates that judicial sensitivity is not neutral; legal boundaries are often unstable and influenced by the social status of the targeted subject and by judges' underlying value assumptions (Mladina d.d. Ljubljana v. Slovenia (No. 2) 2026).

The paper argues that the ECtHR's decision in the Mladina case offers a more coherent interpretation of the law than national courts' rulings, as it adheres to the principle of integrity. The main goal of the research is to perform a Dworkinian analysis of the case, showing whether the reasoning adopted by the ECtHR better satisfies the Dworkinian ideal of law as integrity than the reasoning employed by the Slovenian national courts.

The research is theoretically limited to Dworkin's theory of judicial decision-making, as developed in his later period, particularly in Law's Empire. Specifically, the analytical-regulative ideal of integrity is used to evaluate the case through three pillars: political fairness, material justice, and procedural aspects (Calsamiglia 1994, 58).

Methodologically, the paper adopts a normative and interpretative/hermeneutical approach, conceptualizing law as a normative phenomenon that actively shapes and responds to social dynamics (Merdova et al. 2023). This methodological framework allows for understanding law as a normative phenomenon that is not merely a static set of rules but a dynamic structure that actively shapes and responds to social reality. It is underpinned and accentuated by logical and dialectical methods. Informal logic is employed to ensure the acceptability of argumentation, treating reasoning as a phenomenon rooted in customary legal terminology and language (Bondy 2025, 81-90). Dialectics is employed both internally in the author's reasoning, to arrive at conclusions through a series of arguments and counterarguments, and externally to engage with opposing viewpoints insofar as they are relevant to the aim and topic of the paper (Hohmann 2000, 223-234).

In terms of legal-philosophical theories underpinning the argumentation, a clear value choice in the direction of a Dworkinian approach is made, in line with value incommensurability (Andersson and Hsieh 2025) and Harris's approach of applied theory selection (Harris 1997).

The present analysis also carries direct implications for strategic communication management. The Mladina case illustrates how judicial interpretations of political satire shape the strategic choices available to media organisations and political actors. By clarifying the legal boundaries of provocative expression, the judgment defines the communicative environment in which journalists deploy satire as a tool of public critique and in which public figures manage reputational risks. This dimension underscores the broader relevance of the case for understanding how legal standards influence strategic communication practices in democratic societies.

The paper is organized into four subsequent sections. Section 2 provides a general overview of the Mladina case and the facts of the dispute. Section 3 examines the impact of the ECtHR judgment on the practice of the Slovenian courts and the international free speech doctrine. Section 4 presents the core evaluation through the Dworkinian lens, testing the case against the ideals of integrity. Finally, Section 5 summarizes the findings and assesses the implications for future legal doctrine.

2 OVERVIEW OF THE CASE: MLADINA D.D. LJUBLJANA V. SLOVENIA (NO. 2)

On September 15, 2011, Branko Grims filed a lawsuit as the plaintiff against the defendant company before the Ljubljana District Court. He claimed that the publication of a photo of him and his family in Mladina, compared to Nazi politician and criminal Joseph Goebbels and his family, caused damage to his reputation, good name, and dignity, thereby violating his personality rights. The plaintiff sought non-pecuniary damages totaling 40,001 EUR, along with the mandatory publication of both a formal apology and the court's verdict in Mladina.

The Ljubljana District Court issued a ruling on July 10, 2013, rejecting Grims's lawsuit and denying that the articles, which compared him to Nazi war criminal Joseph Goebbels, unlawfully interfered with the plaintiff's personal rights. The District Court further noted that the articles in question addressed a matter that was then the subject of public debate and concerned a public figure who could be subject to harsher condemnation than the average Slovenian citizen (Mladina d.d. Ljubljana v. Slovenia (No. 2)). Additionally, the court found that the criticism of Grims's behavior constituted a value judgment with a sufficient factual basis and that the disputed photograph was taken at a public event at which the plaintiff voluntarily exposed his family to the public. However, the Ljubljana Higher Court overturned this interpretation (Tivadar 2023, 21).

Grims appealed the above-mentioned judgment to the Ljubljana Higher Court. In its judgment of February 12, 2014, the Ljubljana Higher Court partially granted Grims's appeal. It amended the lower court's ruling, mandating that the magazine publish both a formal apology and the verdict in the same edition. In the part of the decision in which B.G.'s claim for monetary compensation was denied and the costs of the proceedings were decided, the Higher Court annulled the contested judgment and remanded the case to the court of first instance for reconsideration. The court agreed with the first-instance court's decision that the published articles did not infringe on Grims's right to reputation, but found that this did not apply to the publication and comparison of the family photos. It found that it was not necessary to consider all the articles and the publication of the photos as a whole, as the publication of the photos would infringe on the right to privacy to a greater extent than the words (Mladina d.d. Ljubljana v. Slovenia (No. 2)).

Mladina appealed to the Supreme Court against the Higher Court's decision. On September 10, 2015, the court rejected Mladina's appeal, stating that the comparison of the published family photos went beyond merely political methods. Although the court cited the practice of the European Court of Human Rights regarding the importance of freedom of expression in its decision, it ruled differently in this specific case. The court acknowledged that the "Mladinamit" column is satirical and therefore enjoys broader protection, but ruled that the comparison of the family photos exceeded the boundaries of acceptable political criticism. The court found it crucial that the family photos of Branko Grims and Joseph Goebbels were published side by side, in the same size and with almost the same composition. The visual juxtaposition was reinforced by nearly identical captions: "Dr. Goebbels with his family" and "Dr. G. with his family." This, in their opinion, created a multi-layered comparison that was not only about the politician but about the entire family (Mladina d.d. Ljubljana v. Slovenia (No. 2)).

On May 21, 2014, Mladina filed a constitutional complaint against the judgment of the Higher Court of February 12, 2014, and on December 24, 2015, another complaint against the judgment of the Supreme Court of September 10, 2015. Among other things, the magazine claimed that the article was a satirical critique of the politician's behavior rather than a comparison of the two families. The complainant objected to the way the two courts weighed the competing interests in both the narrower and broader contexts, especially regarding the other published material. The Constitutional Court considered both constitutional complaints together and rejected them on December 14, 2016. It determined that the courts in question had provided sufficient reasons for their decisions and had

established a fair balance between the complainant's freedom of expression and the reputation of Grims. It also found that the competent courts correctly applied the relevant criteria from their own case law and from the case law of the European Convention on Human Rights in the specific case.

3 ANALYSIS OF THE IMPACT ON SLOVENIAN AND ECTHR COURT PRACTICE

In understanding the impact of Mladina d.d. Ljubljana v. Slovenia (No. 2) on Slovenian domestic and broader European court practice within the European Court of Human Rights, a critical analysis of the state of the art of case law in both respects needs to be performed. Given the broad scope of decisions, and taking into account the limitations of the present publication format, general contours need to be sketched and important caveats emphasized, while the impact of the case is ascertained.

Freedom of expression sets important limits on the protection of the right to privacy. These two competing interests must be carefully weighed against one another. The criteria typically used to balance these two rights include, among others, the publicity of the right holder's private life, the private or public nature of the place where the event occurred, the purpose of disclosing the information, and the social interest in disclosing it (Trstenjak 2015, 50). Article 10 of the European Convention on Human Rights protects both the content and the form of expression, even when the language may be offensive.

In this regard, the tripartite cumulative test has emerged as the gold standard in ECtHR practice (Gosztonyi, Pribula and Lendvai 2025, 144) and is the framework which not only the ECtHR but also national courts, including those in Slovenia, need to appropriately acknowledge and align their decision-making with. It requires the assessment of whether the interference is prescribed by law, pursues a legitimate aim, and is necessary in a democratic society. The ECtHR's analysis consistently relies on the aforementioned tripartite test, and the judgment highlights that domestic courts often fail to meet the third limb of this test, namely the necessity in a democratic society (Harris et al. 1995, 598).

In analysing the present case, it needs to be understood that Branko Grims was clearly a well-known politician at the time of the publication of the satire. Jurisprudence regarding Article 10 demonstrates that the entire political class is subject to the principle of increased tolerance (Fenwick 2023, 324–333). The Court does not distinguish between different tiers of political life when applying this rule; the doctrine extends universally across the political spectrum, regardless of an individual's specific rank or function.

Thus, a broader structural principle that the ECtHR applies in its reasoning and decisions seems to be reflected in this case. The level of sensitivity that courts show varies according to the institutional, formal, and even social status of the individual or group of individuals that is the target. In this sense, political actors as targets enjoy the lowest level of protection because they voluntarily enter the public arena and because discussing them, their conduct, and opinions freely is of the utmost value for society, not least due to their disproportionate influence (Aftab 2024).

This standard has been consistently applied to the highest levels of the executive branch, including Prime Ministers (Tuşalp v. Turkey; Axel Springer AG v. Germany (no. 2); Dickinson v. Turkey) and cabinet ministers (Turhan v. Turkey), as well as to local authorities such as mayors (Brasilier v. France). Moreover, the ECtHR demands a similar degree of tolerance from political advisers (Morar v. Romania), parliamentary deputies (Mladina d.d. Ljubljana v. Slovenia; Monica Macovei v. Romania), and the leadership of political parties (Oberschlick v. Austria (no. 2)) (Guide on Article 10 – Freedom of expression).

In the case at hand, as the ECtHR decided on the need for a heightened level of protection of satirical expression, an extremely important precedent has been set, reiterating and broadening an existing principle. As has been emphasized by the Court many times, a politician must show greater tolerance than a private individual, particularly when they voluntarily expose their private lives, especially to gain political support. This ruling reaffirms that journalistic freedom is not limited to polite discourse but explicitly includes the possibility of using a degree of exaggeration and provocation (Trstenjak 2015, 52).

Although journalists in Slovenia often face legal pressure through defamation claims, this case set a crucial precedent by elevating the right to public debate above the grievances of political

figures. The decision underscores that public figures' efforts to silence their critics must yield to the media's duty to provide commentary on matters of significant public interest (Global Freedom of Expression).

In relation to national court practice, the ECtHR decision unanimously found a violation of Article 10 of the Convention. In this sense, the Court performed a standard corrective function with respect to the Slovenian national courts (Stoyanova 2026). In insisting that political satire, even when harsh, falls within the scope of permitted freedom of expression as a valuable human right, it once again aligned the interpretative framework of the highest Slovenian national courts with European human rights protection standards.

The judgment in Mladina d.d. Ljubljana v. Slovenia (No. 2) is thus best understood as illustrating the contrast between the restrictive approach adopted by Slovenian courts and the broader protection of political expression developed in the jurisprudence of the European Court of Human Rights. Under Article 10 of the Convention, the Court consistently emphasises that political speech enjoys the highest level of protection and that restrictions on such expression must be interpreted narrowly. In particular, satire is recognised as a form of artistic and social commentary which, due to its inherent exaggeration and provocation, requires especially careful scrutiny when limitations are imposed (Welsh and Silva Canha v. Portugal, § 29). By its nature, satire relies on exaggeration, distortion, and provocation and therefore cannot be assessed according to the same standards as literal factual reporting (Tuyau 2025).

The decision thus once more reiterates that freedom of expression remains one of the areas of human rights where the highest Slovenian national courts continue to apply overly restrictive interpretations in comparison with the case law of the ECtHR. This track record has emerged through prior cases such as Mladina d.d. Ljubljana v. Slovenia (No. 1) (17 April 2014), Čeferin v. Slovenia (Application no. 40975/08, judgment of 16 January 2018), and Cimperšek v. Slovenia (Application no. 58512/16, judgment of 30 June 2020).

This divergence between national and supranational practice is evident in the differential treatment of satirical context, politician tolerance, and necessity, all of which form part of a broader trend in Slovenian jurisprudence. Given its impact on domestic law and its reiteration of protected speech under the ECHR, it provides the material for testing Dworkinian coherence in the subsequent section.

4 DWORKINIAN EVALUATION

In analysing the decision and its influence in line with Ronald Dworkin's theoretical framework from Law's Empire (Dworkin 1986), an applied legal-philosophical approach must be employed. In this sense, the regulative ideal of the discussed hermeneutics needs to be primarily ascertained (Mirmohammasdadeghi 2025). There are two relevant elements to this test, namely fit and justification. The interpretative task requires an assessment of whether the employed hermeneutic is in congruence with the existing legal framework and case law and whether it justifies presenting the legal system in the best possible light.

In sketching the theoretical background, Dworkin's later thought clearly places integrity at the centre of legal interpretation. He sees law as interpretive through and through and judges as carriers of legal thought who must avoid conventionalism and pragmatism and, similarly to writers of a chain novel, employ the interpretation that shows the law and the whole legal system in the best possible light, also considering political fairness, material justice, and relevant procedural norms (Dworkin 1986).

Both in the framework of the European Court of Human Rights and the Slovenian national legal system, which must, in accordance with the Constitution and the signed treaties, be aligned with the European Convention on Human Rights (Flander 2025), freedom of expression is of fundamental importance and is a cornerstone of democratic morality. This includes the protection of satire as a form of expression, which is vital for public discourse (Khalid Ranjha 2025).

Thus, restricting satire beyond the means necessary in a democratic society violates the Dworkinian principle of integrity by treating morally valuable speech as supposedly legally unacceptable. In this

sense, Slovenian courts can be seen as employing a wrongfully moralising understanding of political satire. The ECtHR, in its decision, ensured that coherence was restored. In performing this task, the principle of proportionality was central, as the domestic courts failed to weigh the public status of Branko Grims as a politician and his voluntary public exposure with the social function of satire.

In this sense, Dworkin emphasizes interpreting legal rules not formalistically but within their broader political context, in order to ensure coherence and political fairness (Donato 1988, 1521). In terms of their reasoning, the Slovenian highest courts isolated the photo from the broader prima facie satirical nature of the publication. The decision of the ECtHR thus serves as a prime example illustrating that interpreting law in the best possible light is political, principled, and oriented toward the common good, and not merely emotionally reactive.

First, in terms of fit, the decision of the ECtHR is in line with the existing body of jurisprudence relating to Article 10 of the ECHR, as it emphasizes and underscores the protection of political speech and satire. At the same time, it provides an appropriate justification that freedom of expression needs to be grounded in democratic values, inter alia pluralism and a high degree of tolerance for harsh criticism when such criticism is directed at political actors.

From a theoretical perspective, the reasoning of the Slovenian courts reflects what Dworkin described as conventionalism, namely an interpretative approach that prioritizes formal legal categories over the moral and political principles underlying constitutional rights. This perspective is anchored in the belief that "the law is the law" and that the judge's role is strictly limited to applying it as it "really is," without allowing personal ethics or political context to influence the decision (Dworkin 1986, 114). This reasoning illustrates a clear divergence between the restrictive interpretative approach adopted by Slovenian courts and the contextual and proportionality-based approach developed in the jurisprudence of the ECtHR.

What is especially problematic from the Dworkinian perspective is the overly narrow treatment of the visual comparison between Branko Grims and Joseph Goebbels as an isolated act, rather than as part of a broader satirical publication. This weakens the interpretive fit with established ECtHR jurisprudence, which requires national courts to continually ascertain the necessity of limitations on expression in a democratic society.

The interpretive failure of the Slovenian courts can also be situated in the decision to expand, through consecutive rulings, the scope of impermissible speech. By treating the case in this manner, the courts unwittingly echoed the political allegations of hate speech present in the public debate surrounding the case, not explicitly but by implicitly treating satire as undesirable and morally degrading. In this sense, within the domestic jurisprudence that was later found to be in violation of human rights by the ECtHR, the Constitutional Court's moral assumptions crept into legal reasoning in a manner that undermined integrity (Strohmaier and de Jong 2023).

Furthermore, Dworkin's principle of integrity would require a more careful balancing of social externalities against the common good (Horn 2025). While reputation is an important protected right, freedom of expression in satire, especially in connection with the partly voluntary public exposure of a politician's family, needs to be given precedence in order to ensure integrity in reasoning and to demonstrate the democratic centrality of critique and free discourse, thereby presenting the existing legal system in the best possible light.

This shift from domestic formalistic literalism toward the ECtHR's substantive proportionality review confirms that the law reaches its best possible light when judicial sensitivity is neutral and anchored in the foundational principles of democratic pluralism. By rejecting the restrictive approach of national courts, the ECtHR reaffirms that the protection of political satire is not a mere technicality but a necessity for a functioning state, as the Court consistently maintains that "there can be no democracy without pluralism" (Centro Europa 7 S.r.l. and Di Stefano v. Italy).

If we try to generalise this understanding beyond the confines of the analysed case, the ECtHR can plausibly, in its institutional function, be claimed to be (not only, but also) a Dworkinian court, in the sense that it can be analytically compared to the Dworkinian model of adjudication. It ensures coherence in legal decision-making and reasoning across signatory states and demonstrates how the law can be shown in the best possible light through respect for human rights and the rule of law as the central regulative ideal (Stefanovska 2022, 27–43).

As shown in the analysed case, the ECtHR posits a principled correction of national courts, fosters a contextualised understanding of expression, ensures that proportionality is applied in adjudication, and perhaps most importantly exemplifies and promotes the judicial role as one of normative interpretation. It can thus be considered Dworkinian in the sense that it integrates law and morality and often successfully highlights the dangers of formalist or pragmatic adjudication, bringing corrective balance to the decisions of the highest national courts.

Specifically in the analysed case, it ensured coherence and integrity by reaffirming that the protection of political satire is not a mere technicality but a necessity for a functioning democratic state and that "there can be no democracy without pluralism" (Centro Europa 7 S.r.l. and Di Stefano v. Italy).

5 CONCLUSION

Thus, based on the critical analysis of the case Mladina d.d. Ljubljana v Slovenia (No. 2), we have shown that judicial sensitivity is indeed not neutral. The reasoning of the ECtHR and its correction of the formalistic approach of Slovenian highest courts has shown the relative non-stability of argumentative boundaries and the way that courts can treat satire as pseudo hate-speech due to their overbearing sensitivity, even when the case concerns traditionally non-hate speech related questions pertaining to freedom of expression.

Evaluation of the decision in light of the Dworkinian regulative ideal of integrity, combined with political fairness, material justice and procedural requirements has shown that the ECtHR has shown both the national and supranational human rights law in a better light than the approach taken by the national courts. In this sense, ECtHR often performs the role of a true 'Dworkinian' judge, ensuring the coherence both in ECHR practice and across national jurisdictions.

With the reasoning and decision in the analysed case, the social function of satire was underscored and shown not to be a mere entertainment of even a morally unacceptable form of communication, but a necessarily permitted form of expression in a functioning pluralist state, especially in the cases concerning politicians as public figures.

The potential for further research is expansive. Primarily the Dworkinian approach, in terms of applied philosophy, could be utilised to analyse other legal issues, case law or legislation. Although his doctrine has been studied in considerable depth from the standpoints of legal philosophy and theory, the applied aspect remains scarce. Furthermore, a more in depth delve in the Slovenian court practice and sociologically reasons for a higher degree of formalism and restrictiveness could be subjected to reasoned argumentation and even empirical research. In interdisciplinary terms, the influence of court decisions, both on national and supranational levels, on the discipline of strategic communication could be studied.

The case Mladina d.d. Ljubljana v Slovenia (No. 2) once more underscores the need for supranational human rights abjudicative bodies that serve as a corrective to national courts. From a Dworkinian standpoint, this is relevant especially when national courts fail to uphold the democratic ideals in the best possible light and drift into unprincipled pragmatism or rigid formalism. The decision in the analysed case is a welcome contribution by the ECtHR to uphold the appropriate approach to satire and political speech and calls for a renewed reflection of Slovenian and other domestic courts.

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WEB AND INFORMATION TECHNOLOGIES

1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

USE OF ARTIFICIAL INTELLIGENCE FOR DETECTING UNWANTED SMS MESSAGES: ANALYSIS OF METHODS AND EXPERIMENTAL VALIDATION

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ABSTRACT

This study investigates the use of artificial intelligence (AI) methods for detecting unwanted SMS messages, comparing traditional techniques, machine learning (ML) algorithms, and deep learning (DL) models. The theoretical part presents a systematic literature review covering rule-based methods, ML, and DL approaches across 28 analyzed studies. The empirical validation was conducted using the UCI SMS Spam Collection dataset, consisting of 5,538 English messages after preprocessing. The dataset was preprocessed through text cleaning, normalization, tokenization, and Porter Stemmer-based stemming, which reduced vocabulary size by 49.5% and structured the data for vectorization. Experiments were conducted under a standardized benchmarking framework utilizing Multinomial Naive Bayes (MNB), Support Vector Machine (SVM), Random Forest (RF), Convolutional Neural Networks (CNN), and Bidirectional Long Short-Term Memory (BiLSTM) models. Methodological standardization was ensured using unified TF-IDF representations for ML and FastText embeddings for DL models. Our experimental results reveal that traditional ML models achieved the highest classification performance, with MNB and SVM both reaching an accuracy of 97.92%, and SVM obtaining the top F1-score of 91.99%. Conversely, the DL models (CNN and BiLSTM) demonstrated competitive accuracies but lower F1-scores of 90.25% and 87.78%, respectively. Furthermore, ML models proved to be significantly faster and more computationally efficient; MNB required a mere 5.18 seconds to run, while BiLSTM was the most resource-intensive, taking 266.63 seconds. These findings contradict the prevailing literature trend where DL models report the highest average accuracies (97.73%). This discrepancy underscores that direct transfer of literature results is highly sensitive to experimental protocols, dataset constraints, and vocabulary sizes. Ultimately, while DL holds potential for larger datasets, traditional ML remains highly effective and optimal for real-time, resource-constrained environments.

Keywords: *artificial intelligence, SMS detection, machine learning, deep learning*

1 INTRODUCTION

Spam SMS messages are becoming an increasingly significant problem in the modern digital era for all mobile device users. Even though the problem of spam in electronic communication has been a widely researched topic in current technology, the identification of spam SMS messages has been a unique challenge in itself because of the differences in SMS communication when compared to other forms of electronic communication. The main differences in SMS communication are the limitations in the message size, use of abbreviations, grammatical errors, and use of jargon in the messages (Hidalgo et al. 2006; Akande et al. 2021).

The problem of spam SMS is more than just an annoyance for the user. This type of message is commonly identified as being part of phishing scams, the distribution of malware, and money fraud. Conventional filtering techniques that depend solely on simple rules and keyword filtering meet limitations regarding the identification of more sophisticated forms of SPAM messages that constantly vary and adapt to evade the filters (Abdulhamid et al. 2017; Hapase and Patil 2024; Salman et al. 2024; Saeed 2023).

On the other hand, artificial intelligence presents exciting prospects in this regard. Various machine and deep learning algorithms have proven their utility in combating spam emails. However, the question remains how effective these methods are when dealing with the specific challenges of SMS messages (Saidat et al. 2024; Saeed 2023).

Addressing this problem is crucial for improving the mobile user experience and ensuring security. The experience gained and the knowledge acquired can also be applied to other communication channels (Saeed 2023; DasGupta et al. 2021; Giri et al. 2023).

In order to present a comprehensive analysis, we have divided the paper into two parts. Firstly, we have performed a literature review-based analysis in terms of the methodology categorized by type, as well as the most common algorithms, and then we have validated the methodology experimentally. The tests were performed within a standardized framework in the same dataset. This lessened the influence of something that, in most instances, makes a direct comparison between results difficult.

2 PURPOSE AND GOALS

The objectives of this research were to investigate and evaluate the effectiveness of various artificial intelligence techniques for detecting spam SMS messages. Based on a review of the relevant literature, the study aimed to identify the most suitable technique for this problem.

Specifically, the objectives were to conduct an objective analysis of existing methods used for spam SMS detection, to compare the relative effectiveness of different artificial intelligence approaches, and to implement the most promising technique identified in literature. In addition, the study sought to evaluate the proposed approach using a real-world dataset, to identify the key challenges and limitations of the research, and to outline directions for future work.

Hypotheses:

- H1: Traditional machine learning models achieve significantly higher classification accuracy in SMS spam detection compared to rule-based and keyword-filtering methods.
- H2: Comprehensive text preprocessing significantly reduces dataset noise and vocabulary size, thereby improving the overall performance of the classification models.
- H3: Deep learning models yield superior detection performance (higher accuracy and F1-score) in SMS spam classification compared to traditional machine learning algorithms.

3 METHODS

Based on the systematic literature review, we conducted a quantitative analysis of the performance of different approaches for spam SMS detection. The goal was to use the data extracted from the analyzed studies to identify the most suitable and most promising approaches for implementation. The analysis covers examples of traditional methods, machine learning methods, and deep learning methods, focusing on classification accuracy as the primary criterion and on the consistency of results across different studies.

For this purpose, we collected and analyzed 28 studies (Saeed 2023; Saputra 2024; Dharrao et al. 2024; Raharja et al. 2022; Astuti et al. 2024; Hidalgo et al. 2006; Almeida et al. 2011; Hameed 2021; Triana et al. 2025; Charanarur et al. 2023; Kumar et al. 2023; Johari et al. 2025; Airlangga 2024; DasGupta et al. 2021; Kim, Jo, and Choi 2015; Nagare et al. 2024; Gedam 2025; Choubey 2021; Khemapatapan 2010; Taylor and Robert 2025; Almeida et al. 2013; Abid et al. 2022; Awad and Elseuofi 2011; Sumathi and Raja 2023; Ahmed and Haruna 2025; Agarwal et al. 2024; Rustam et al. 2023).

After analyzing the selected literature, we found that the SMS Spam Collection Dataset (UCI) appeared most frequently, being used in more than 40% of the analyzed studies. For this reason, we selected the UCI SMS Spam Collection Dataset for our validation, as it represents a standard benchmark in the research community for SMS spam detection and enables direct comparison of results with existing work.

All tests were performed on the UCI SMS Spam collection data set (Almeida et al. 2011). While the original UCI SMS Spam Collection contains 5,574 messages in total, the final dataset analyzed in this study comprises 5,538 English language-only messages, following the removal of 36 duplicate entries, non-English messages, or incomplete records during the initial data filtering phase. This processed dataset maintains a ratio between legitimate and spam messages of 6.4:1.

For the machine learning experiments (MSB, SVM, RF methods), we processed the dataset and split it as follows:

- Total size: 4,430 samples for TF-IDF vectorization
- TF-IDF matrix: 4,430 × 5,000 features
- N-grams: 1–2
- Number of features: 5,000
- Train/test split: 80/20

For the deep learning experiments (CNN, LSTM methods), the data were split as follows:

- Training: 3,876 samples (70%)
- Validation: 554 samples (10%)
- Test: 1,108 samples (20%)

As part of preprocessing, we removed stop words using the Python NLTK library and filtered out words shorter than three characters. Finally, we applied stemming with the Porter Stemmer. As shown in Table 1, the examples of a legitimate message before and after preprocessing, as well as a spam SMS message before and after preprocessing, indicate that preprocessing significantly reduces noise while preserving semantically important words. Preprocessing improved the structure of the data, providing a solid foundation for subsequent vectorization/embedding and classification.

Table 1: Overview of metrics after preprocessing

Metric	Before	After	Reduction (%)
Average message length (characters)	80.5	44.6	44.6%
Average number of words	15.6	8.0	48.9%
Vocabulary size	13579	6864	49.5%
HAM messages (characters)	71.5	39.7	44.4%
SPAM SMS messages (characters)	138.7	75.8	45.3%

(Source: Authors' own work; applies to all subsequent tables)

For the traditional machine learning methods, we used a unified TF-IDF representation in order to eliminate the influence of differences in feature extraction and ensure that performance comparisons between models primarily reflect the capabilities of the algorithms themselves rather than differences in the input data representation. The same TF-IDF configuration (matrix 4,430 × 5,000, 1–2 n-grams) was used for MNB, SVM, and RF, thereby ensuring methodological standardization and reproducibility.

Given that, we standardized the preparation of input data for the deep learning models so that the comparison between CNN and BiLSTM would not be dependent on different text representations.

Messages were tokenized, a vocabulary was built, and tokens were mapped to indices; the texts were then converted into fixed-length sequences by padding or truncation. Such sequences were fed into FastText embeddings able to handle more effectively, because of the subword units, abbreviations, errors, and rare words-characteristics very common in SMS messages. The same pipeline was used for both deep models to ensure standardization and reproducibility of results.

To enable an objective comparison of results, we also defined a standardized test protocol consisting of five test messages. All models were evaluated using these messages, allowing a direct comparison of predictions and probabilities across models.

For each model, training and testing were performed in three independent runs, enabling an assessment of variability and the calculation of average metrics. All experiments were conducted under identical conditions using the same data splits.

Performance was measured using Accuracy and F1-score (a model performance evaluation metric used for assessing and reporting results in spam detection), as well as the elements of the confusion matrix (TP (True Positive), FP (False Positive), FN (False Negative), TN (True Negative)). For deep learning, we report averages across multiple runs due to the stochastic nature of training.

4 RESULTS

Systematic Literature Review Findings

The results obtained in the analysis of the literature are shown in Tables 2 and 3. Table 2 gives an overview in different categories, and Table 3 shows results for the different methods in the literature.

Table 2: Overview of Accuracy by Category

Category	No. of studies	Min. accuracy (%)	Max. accuracy (%)	Mean(%)	Median(%)	Std. dev.
Traditional	6	72.65	99.81	92.11	95.45	10.15
Machine learning	84	84.40	99.70	96.35	97.24	2.90
Deep Learning	37	92.00	99.98	97.73	98.25	1.93

While machine learning is in the dominant spot with 84 related methods (66.1%), deep learning follows next with 37 methods (29.1%), and then comes the traditional approaches with just 6 methods (4.7%). Traditional approaches report the lowest accuracy (92.11%) and the highest variation of all, machine learning reports the next highest accuracy of 96.35%, good consistency while deep learning reports the highest accuracy of 97.73%, as well as the lowest variation of all.

Table 3: Performance Analysis of Individual Methods

Algorithm	No. of studies	Min (%)	Max (%)	Mean (%)	Std. dev.
CNN	14	95.30	99.98	98.85	0.95
XGBoost	3	96.47	99.41	97.69	1.53
BERT	3	92.00	99.28	96.65	4.03
LSTM	14	93.40	99.79	96.90	1.84
SVM	18	90.68	98.95	96.68	2.28
RF	13	86.70	99.70	96.38	3.35
MNB	22	84.40	99.46	96.25	3.69
Logistic Regression	11	91.80	99.00	96.25	2.51

The systematic review of studies from the literature provided insight into the suitability of individual methods for SPAM SMS detection. Based on these results, we decided to use MNB (Multinomial Naive Bayes), SVM (Support Vector Machine), RF (Random Forest), CNN (Convolutional Neural Network), and LSTM (Long Short-Term Memory) for the experimental validation of findings reported in the literature.

In our analysis of the existing literature, we found that traditional approaches tend to achieve lower average accuracy and exhibit high variability. Machine learning was the most frequently used category in the selected studies and showed a high degree of stability, while deep learning achieved the highest mean accuracy with the lowest variability. At the algorithm level, CNN stands out with the highest average performance and a low standard deviation.

Experimental Benchmarking Results

As shown in Table 4, MNB and SVM achieved the highest accuracy (97.92%), with SVM also obtaining the highest F1-score. The implemented deep learning methods, CNN and BiLSTM, achieved lower F1-scores compared to the machine learning approaches.

Table 4: Comparison of average values across the tested models

Method	Accuracy	F1-score	TP	FP	FN	TN
MNB	0.9792	0.9187	130.0	4.0	19.0	955.0
SVM (RBF)	0.9792	0.9199	132.0	6.0	17.0	953.0
RF	0.9756	0.9011	123.0	1.0	26.0	958.0
CNN	0.9756	0.9025	125.3	3.3	23.7	955.7
BiLSTM	0.9684	0.8778	125.7	11.7	23.3	947.3

An important metric for SPAM SMS detection methods is also runtime. For this reason, we measured the total time including hyperparameter optimization, training, and testing on new messages. The average times obtained from three runs were:

- MNB: 5.18 s
- SVM: 91.90 s
- RF: 162.83 s
- CNN: 31.33 s
- BiLSTM: 266.63 s

5 DISCUSSION

The analysis of the literature identifies an advantage for deep learning by average accuracy and robustness, with CNN as best performing algorithm. However, the experimental part shows that MNB and SVM algorithms yield comparable or even better performance than deep learning on standardized conditions on short SMS texts, requiring less computation. This could indicate that a direct transfer of results found in the literature is not always possible without taking into consideration the used experimental protocols such as: preprocessing, representation, data splits - and size of the corpus.

Based on our experimental findings, we explicitly address the status of the formulated research hypotheses:

- **Hypothesis 1 is confirmed.** The evaluated machine learning models (MNB, SVM, and RF) achieved high classification accuracies ranging from 97.56% to 97.92%, representing a substantial improvement over basic rule-based and traditional keyword methods, which showed a lower mean accuracy of 92.11% in the literature.
- **Hypothesis 2 is confirmed.** Text preprocessing played a critical role in structuring the raw SMS texts. By reducing the total vocabulary size by 49.5% and the average message length by 44.6%, the preprocessing pipeline successfully eliminated textual noise, providing a clean dataset that led to robust and stable performance across independent training runs.
- **Hypothesis 3 is rejected.** Contrary to the general literature trend where deep learning models report higher accuracies, our standardized empirical validation demonstrated that traditional ML models (specifically MNB and SVM) achieved higher F1-scores (91.87% and 91.99% respectively) compared to CNN (90.25%) and BiLSTM (87.78%), while requiring exponentially less computational time.

Differences between methods are also reflected in their error profiles. RF behaves conservatively (very low FP, higher FN), which reduces false alarms but increases the risk that SPAM SMS slips through detection. CNN shows variability across runs, which is typical for neural networks, whereas BiLSTM is the most time-consuming and produces more false alarms (FP), even though its results remain relatively stable.

The results also highlight various attributes associated with SMS-based communication, which are critical to the detection model's performance. The short average message length was only 44.6 after preprocessing, thus providing less contextual information, essential for deep learning models. The class imbalance problem, where the HAM:SPAM ratio is about 6.4:1, is a common phenomenon for the models, as observed in lower recall values for the spam class versus nearly perfect recall values for the ham class.

The limited dataset size (5,538 messages) is an important constraint for deep architectures, which typically require larger amounts of data for optimal learning. Language specificity is another limitation (testing exclusively on English data). The dataset also does not currently represent state-of-the-art sender tactics. Thus, it should be used with caution when generalizing results to the current environment. Temporal drift in SPAM SMS content is not accounted for, as the UCI dataset may not capture contemporary strategies. The lack of metadata restricts the models to text-only analysis; integrating additional features could further improve detection. The time efficiency of traditional algorithms suggests that MNB and SVM are well suited for real-time applications, particularly on mobile devices.

This suggests that the choice of method is also context dependent. If the priority is speed combined with robust performance under constrained resources, then MNB/SVM are the logical choice. If the data set is larger, better updated corpora are available, and infrastructure is sufficient, then there is a potential to obtain extra performance from deep models, but the stochasticity and deployment costs must also be considered.

6 CONCLUSION

The scientific work addressed the challenge of detecting spam SMS messages using artificial intelligence methods. A literature review showed the dominance of machine learning methods in the research space and highlighted CNN as the algorithm with the highest average accuracy and high consistency. Experimental validation on the UCI SMS Spam Collection shows that MNB and SVM achieved the highest F1-score under standardized conditions, while deep models are competitive but more time-consuming. In conclusion, while Hypotheses 1 and 2 were fully confirmed by our findings, Hypothesis 3 was rejected, demonstrating that deep learning does not automatically guarantee superior performance over well-tuned, traditional machine learning models in short-text and resource-constrained scenarios.

The key contribution of the article lies in the combination of literature analysis and repeatable experimental validation, which shows that the best method is not universal, but is conditioned by domain properties, data size and operational constraints. Further work should be directed towards newer and larger corpora, multilingualism, analysis of spam temporal drift and the use of a combination of different models.

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1.08 Objavljeni znanstveni prispevek na konferenci
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CYBERSECURITY AWARENESS AMONG OLDER ADULTS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

An ageing population and accelerated digitalisation pose numerous challenges in the field of digital inclusion, security, and protection of older adults. Although they are not the primary target of attackers, older users may face heightened vulnerability due to lower digital literacy, limited access to support, and psychosocial factors that increase exposure to cyber threats. This paper presents a systematic literature review examining cybersecurity awareness among older adults. In accordance with the PRISMA methodology, the review was conducted using IEEE Xplore, Web of Science, and Scopus, resulting in the inclusion of 14 studies in the final analysis. The findings were categorised into four areas: (1) demographic and contextual factors influencing awareness, (2) common types of cyberattacks affecting older adults, (3) security practices, and (4) awareness-raising and educational approaches. The results highlight the pronounced heterogeneity of the older population and indicate that cybersecurity awareness is not determined solely by age but is associated with factors such as education, digital skills, access to support, and life circumstances. The reviewed studies identify phishing, identity theft, romance scams, and other forms of socially engineered deception as important cybersecurity threats. Security practices vary considerably, and awareness of cyber risks does not necessarily translate into consistent protective behaviour. Although several educational approaches appear promising, the available evidence is insufficient to determine which programmes are most effective. The findings therefore underscore the need for practical and accessible support alongside stronger empirical evaluation of cybersecurity interventions for older adults. A comprehensive understanding of these factors is essential for promoting safe and confident digital participation in later life.

Keywords: *older adults, cybersecurity awareness, silver surfers, online security*

1 INTRODUCTION

Globally, two major megatrends can be observed that carry profound socio-economic implications for the world's population: population ageing and the rapid development of digital technologies. Although these trends are intensifying simultaneously, their correlation is not necessarily positive. On average, older adults are less engaged with digital technologies, which may exacerbate digital inequalities and increase vulnerability in online environments. The level of digitalisation is rising sharply worldwide (IMD 2024), while in Europe, public policies and legislative measures aim to ensure that by 2030 at least 80% of the population will possess basic digital skills—an objective considered essential for competitiveness and innovation (European Commission 2022). Numerous studies highlight the positive effects of technology on the lives of older adults, including faster access to information and services (such as shopping, banking, healthcare, and public administration) (da Silva et al. 2023; Jin and Fan 2022; Money et al. 2024), the maintenance of social connections (Chopik 2016; Cotten et al. 2013), and opportunities for education and lifelong learning (Liyanagunawardena and Williams 2016). However, the very domains in which older adults use digital technologies and derive substantial benefits also raise critical cybersecurity concerns. In its first report of this kind, *Ageing in a Digital World – From Vulnerable to Valuable*, the International Telecommunication Union (ITU) emphasises that exposure to risks and the potential impact of abuse increase when user interfaces are poorly designed, procedures are overly complex, or when users—due to accessibility barriers—are compelled to rely on third-party assistance, thereby sharing sensitive personal data. Consequently, cybersecurity in later life is not solely a matter of individual user knowledge. Rather, it also depends on (1) the design of age-friendly digital environments, (2) effective consumer protection, and (3) systemic support mechanisms, which together reduce vulnerabilities and enable safe, confident, and inclusive digital participation (International Telecommunication Union 2021).

Cybersecurity is a broad and frequently used concept whose meaning is not unambiguous. In general, it refers to a set of measures, practices, and technologies designed to protect information systems, networks, and data from unauthorised access and misuse (Cains et al. 2022). The primary objective of cyberattacks is often to gain access to a target system, thereby enabling attackers to obtain (sensitive) data and to modify or destroy it (Schilirò 2023). Cybersecurity, therefore, extends beyond the technical protection of systems to encompass user awareness of online risks and the safe handling of data in digital environments. Cyberattacks can be distinguished by their intent, scope, and level of interaction with the compromised system, including active and passive attacks (Uma and Padmavathi 2013).

Among the most common forms of online fraud is phishing, in which attackers impersonate trusted individuals or organisations in order to obtain users' personal and authentication credentials. This is most commonly achieved by sending messages containing deceptive content and embedded links that, once clicked, redirect users to fraudulent websites where they unknowingly enter their information (Jang-Jaccard and Nepal 2014). Social engineering also plays a crucial role in such attacks, as it relies on the psychological manipulation of users. Attackers exploit trust, fear, curiosity, or a sense of urgency and use deceptive tactics to persuade users to disclose sensitive information or to perform actions that compromise their security. A further common manipulative strategy employed by cybercriminals involves so-called "romance scams", in which perpetrators use fabricated identities and establish emotional relationships with potential victims via online dating platforms in order to gain their trust (Uma and Padmavathi 2013).

Although the technical protection of systems through antivirus software and firewalls is essential, the human factor remains the weakest link in the security chain. The term *cyber hygiene* is frequently used in the literature to refer to a set of recommendations and best practices that help individuals maintain the security of their digital devices and data, thereby reducing their vulnerability to cyberattacks (Howell et al. 2024). These practices include using strong, complex passwords, implementing two-factor authentication, regularly updating software, carefully verifying suspicious email messages, and continuing education on emerging forms of online fraud and protection strategies (ENISA n.d.).

Older adults are not necessarily more likely than younger adults to report financial losses from fraud. However, when financial losses occur, older adults tend to report higher median individual losses, indicating that the financial consequences of fraud may be particularly severe in later life (Federal Trade Commission 2025). Morrison et al. (2023) identify six key dimensions of heteroge-

neity among older adults that shape their cybersecurity-related needs: (1) cybersecurity awareness (understanding of threats and recommended practices), (2) availability of support (access to assistance from family members, the community, or professionals), (3) digital literacy (practical skills for the safe use of technology), (4) stress and anxiety (emotional burden that may lead to avoidance or inaction), (5) financial situation (the ability to access appropriate devices and protective tools), and (6) perceived responsibility for security (whether individuals view security as their own responsibility or as that of organisations or the broader system).

Thus, cybersecurity and awareness are closely tied to older adults' well-being and active ageing, enabling safe digital participation, trust in services, and independence. Conversely, experiences of cyberattacks can heighten fear, reduce engagement with online services, and lead to partial or complete digital withdrawal.

2 PURPOSE AND GOALS

The purpose of this paper is to comprehensively synthesise empirical findings on cybersecurity awareness among older adults through a systematic literature review, and to identify key factors, risks, behavioural practices, and effective awareness-raising approaches. The objective is to develop a structured overview of the existing literature that can serve as a foundation for the design of age-friendly educational programmes and support measures to enable the safe digital participation of older adults. Based on the theoretical review of the literature, four research questions were formulated:

RQ1: Which demographic factors influence cybersecurity awareness among older adults?

RQ2: What are the most common types of cyberattacks on older adults?

RQ3: Which security practices are most commonly adopted by older adults (e.g., strong passwords, software updates, antivirus protection)?

RQ4: Which programmes (educational initiatives, workshops, or other interventions) are effective in raising awareness of the importance of cybersecurity among older adults?

3 METHODS

To gain a comprehensive understanding of older adults' cybersecurity awareness and exposure to cyberattacks, we conducted a systematic literature review. The aim was to identify and analyse studies examining cybersecurity awareness among older adults. Relevant studies were reviewed to identify key findings, trends, and research gaps. The review followed sequential steps, including selecting digital libraries, formulating search strings, defining inclusion and exclusion criteria, and applying a structured selection process with title/abstract screening, duplicate removal, and full-text review, yielding the final set of studies for analysis.

To capture both social science and technical perspectives, we included IEEE Xplore for computer science and IT research, alongside Web of Science and Scopus, which cover both technical and social science studies, including social gerontology. This approach ensured a comprehensive, interdisciplinary perspective.

The search string was developed based on pre-defined inclusion keywords reflecting the key concepts of the research topic, such as "cybersecurity awareness", "older adults", and "self-efficacy". Using these concepts, we constructed a comprehensive search string applied for the literature review: *(older adults OR elderly OR seniors OR ageing) AND (cybersecurity OR information security OR cyber attack* OR security risk* OR security practice*) AND (cyber awareness OR self-efficacy OR cyber skill* OR digital literacy OR competence).*

The application of predefined inclusion and exclusion criteria enabled a consistent and transparent selection of studies relevant to the research questions. These criteria were applied in the first step of the study selection process, ensuring that the initial selection included only articles that met the chosen temporal requirements, publication language, full-text availability, and relevance to cybersecurity awareness among older adults. The selected inclusion and exclusion criteria are presented in Table 1.

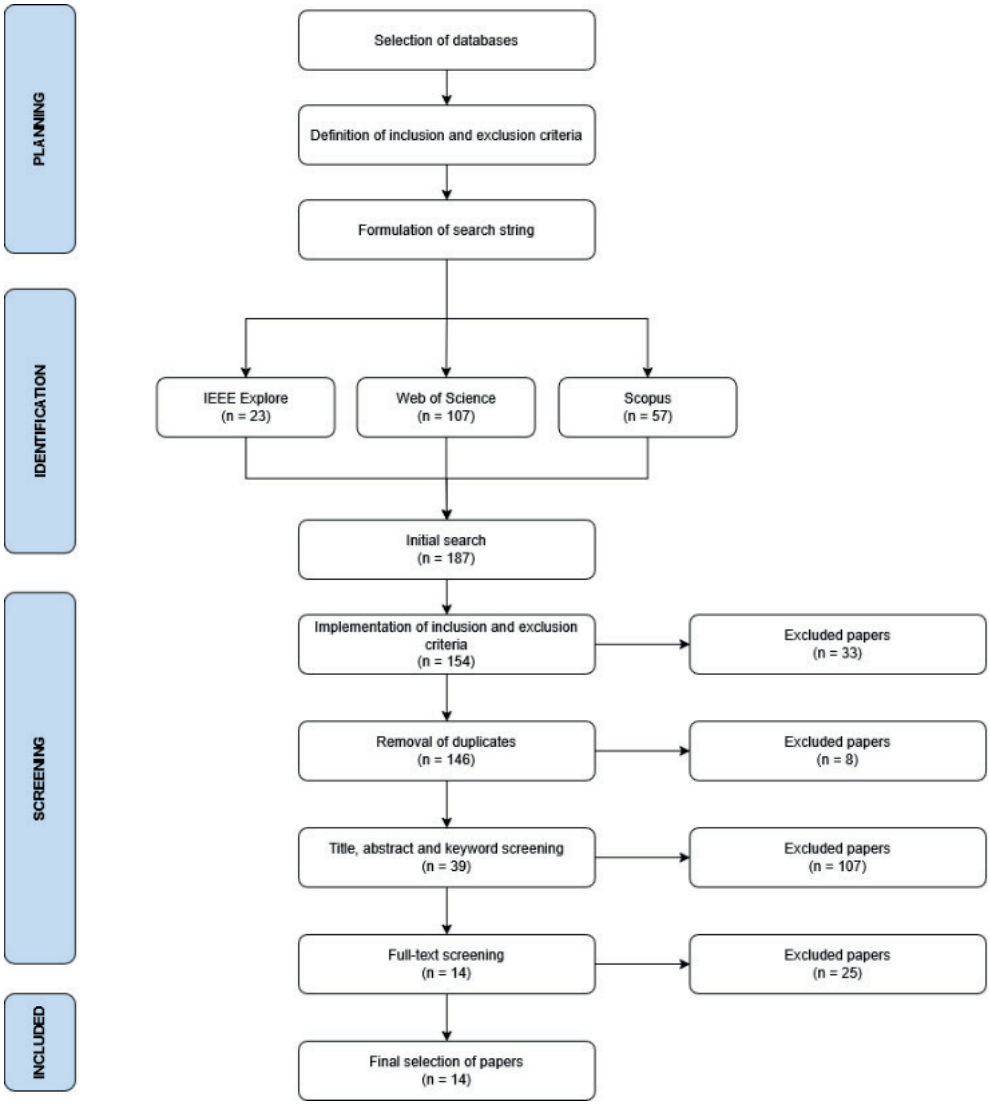
Table 1: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
The source was published between 2020 and 2025	The source is not fully accessible
The source is written in English.	The source does not address cybersecurity awareness among older adults (60+).

(Source: Authors' own work)

3.1 Study selection process

Figure 1: PRISMA diagram



(Source: Authors' own visualisation)

The study selection was conducted according to the PRISMA method, a standardized procedure for selecting studies in systematic literature reviews. The entire process is illustrated in Figure 1. PRISMA enables a structured presentation of the procedure, comprising four phases: review planning, source identification, primary study selection, and the formation of the final set of studies.

4 RESULTS

Following the initial search in the selected databases, a total of 187 sources were retrieved: 23 from IEEE Xplore, 107 from Web of Science, and 57 from Scopus. After applying the inclusion and exclusion criteria, 33 articles were excluded from this set for not meeting the criteria regarding publication year, accessibility, or language. Subsequently, duplicate records across the databases were identified, totalling 8. As a result, the initial pool of sources was reduced to 146 articles. The initial selection showed that the literature on older adults' cybersecurity awareness is extensive but heterogeneous, with the Web of Science contributing the most articles, IEEE Xplore providing technical studies, and Scopus offering a mix of technical and social science research.

This was followed by a screening of the collected sources based on their titles, keywords, and abstracts. This approach allowed us to efficiently narrow the pool of studies to those relevant for further, more detailed analysis.

The final set of 14 studies was analysed according to four predefined thematic categories:(1) demographic and contextual factors associated with cybersecurity awareness among older adults, (2) types of cyberattacks affecting older adults, (3) security practices reported by older adults, and (4) awareness-raising and educational approaches. Table 2 presents the characteristics of the included studies, including country, methodology, sample size and main thematic focus.

Table 2: SLR results

Authors	Country	Methodology	Sample size	Main focus/findings
O'Keeffe et al. 2025	Ireland	Semi-structured interviews	77	Phishing exposure, banking security; differences by tech-use level
Ahmad Nawi et al. 2025	Malaysia	Survey	60	Awareness gap; malware and ransomware awareness, informal learning via family
Parti et al. 2025	United States	Survey	1113	Age, education, income, well-being and internet access as factors associated with cybersecurity learning preferences
Morrison et al. 2020	United Kingdom	Semi-structured interviews	12	Retirement transition; loss of social interaction, routines and technology support; implications for cybersecurity vulnerability
Zhai et al. 2025	China	Participatory design workshops	10	Deepfake scams; emotional and social factors shaping vulnerability
Sayeed et al. 2025	Bangladesh	Prototype only	Platform design	AI-supported awareness platform; no empirical evaluation
Vrhovec et al. 2024	United Kingdom	Survey	502	Mobile device competence; availability of support
Yin et al. 2024	United Kingdom	Survey	31	Digital literacy, fear, anxiety, and reduced confidence in online safety
Morrison et al. 2021	United Kingdom	Task-assisted interviews	19	Safe password use and regular updates awareness
Fujs et al. 2025	United Kingdom	Survey	784	SmartICST segmentation of older adults into 5 cybersecurity profiles
Maughan et al. 2025	United States of America	Interviews	12	Best practices for teaching older adults: analogies, small groups, repetition
Datti et al. 2025	India	Semi-structured interviews	30	Safe behaviours; reliance on family; verifying sources; avoiding public Wi-Fi
Alieyah et al. 2023	Malaysia	Interviews with experts	2	SCSAM-Elderly model: social, personal, organisational factors
Tan et al. 2025	Malaysia	Interviews	13	Cybercrime vulnerability; phishing, identity theft and impersonation-based scams; emotional and psychological impacts

(Source: Authors' own elaboration based on the reviewed literature)

4.1 Demographic factors associated with cybersecurity awareness among older adults

Parti et al. (2025) found that age, education, subjective well-being, and access to reliable high-speed internet were associated with preferences for cybersecurity education. Education showed selective positive associations, particularly with preferences for interactive learning formats, whereas income was largely unrelated to learning preferences. Zhai et al. (2025) showed that living environment (urban vs. rural) affects access to support and information relevant for recognising scams, with urban participants having more digital literacy resources. Vrhovec et al. (2024) reported that competence in using mobile devices and availability of support are positively associated with cybersecurity competence. Yin et al. (2024) observed that limited digital skills amplify fear and reduce confidence in safe online behaviour. Morrison et al. (2020) highlighted that the transition to retirement may involve losses in social connections, routines, and technical support, increasing exposure to online risks.

4.2 The most common types of cyberattacks targeting older adults

O'Keeffe et al. (2025) found that 19% of participants had encountered phishing attempts. Alieyah et al. (2023) reported that older adults often fail to recognise or report fraud attempts, increasing the impact of identity theft. Tan et al. (2025) observed that identity theft is more prevalent in areas with public Wi-Fi networks due to lower security levels. Romance scams were identified as a particularly common form of social engineering, with older widows with higher education and greater wealth being especially vulnerable (Tan et al. 2025). Attackers often use "fake gifting" tactics to manipulate victims into paying fraudulent fees.

4.3 Security practices used by older adults for protection against cyber threats

O'Keeffe et al. (2025) reported that more digitally literate older adults commonly avoid public Wi-Fi networks, use two-factor authentication, and verify sources, especially in financial contexts. Less digitally literate individuals often avoid digital transactions or rely on family members for assistance. Datti et al. (2025) found that older adults frequently rely on family support, verify information sources, avoid public networks, and exercise caution when sharing personal data. Morrison et al. (2021) observed that some older adults deliberately avoid regular software updates due to perceived inconvenience, effort, or fear of making mistakes. Ahmad Nawi et al. (2025) identified a gap between awareness and behaviour, noting that users often understand cyber threats but fail to implement protective measures consistently.

4.4 Awareness and educational programs to enhance cybersecurity among older adults

Vrhovec et al. (2024) and Alieyah et al. (2023) highlighted the importance of training and awareness programs. Sayeed et al. (2025) proposed an AI-supported awareness platform but did not conduct empirical evaluation. Maughan et al. (2025) identified best practices for teaching cybersecurity to older adults: practice-oriented workshops, use of analogies, small-group or individual instruction, and regular reinforcement. Existing studies rarely compare in-person and digitally supported approaches using standardised outcome measures. Prototype learning models presented in the literature have not yet been tested in practice.

5 DISCUSSION

Regarding RQ1, the findings indicate that cybersecurity awareness among older adults cannot be explained by chronological age alone. Instead, it is associated with a combination of demographic and contextual factors, particularly education, digital skills, access to support, living environment, and life transitions such as retirement. Education appears to be relevant to cybersecurity learning preferences, while digital competence and access to support are associated with greater cybersecurity competence. Conversely, limited digital skills may increase fear and reduce confidence in safe online behaviour. The findings also suggest that retirement may represent a period of increased vulnerability, as changes in daily routines and the loss of social and technical support can affect older adults' ability to manage cybersecurity risks. This interpretation is consistent with broader research on digital literacy among older adults. Khan et al. (2026), in a scoping review of 22 studies, found

that barriers to digital literacy result from interacting individual, social, and contextual factors, including support networks, knowledge and information, and resource constraints. Similarly, Oh et al. (2021) emphasised the need for age-appropriate approaches to understanding and measuring digital literacy among older adults. Taken together, these findings reinforce the view that older adults constitute a heterogeneous population and that cybersecurity awareness should be understood in relation to individuals' digital and social resources rather than age as an isolated demographic characteristic.

Regarding RQ2, the findings suggest that the cyber threats affecting older adults share an important characteristic: many rely on deception and psychological or emotional manipulation rather than exclusively on technical vulnerabilities. Although the reviewed studies report different forms of cybercrime, the prominence of socially engineered attacks indicates that vulnerability cannot be understood solely in terms of technological competence. Emerging forms of deception, such as deepfakes, may further complicate the recognition of fraudulent digital content. These findings are broadly consistent with the systematic review by Shang et al. (2022), which examined internet fraud victimisation among older adults and included forms of online fraud such as phishing, romance scams, grandparent scams, and social networking fraud. Importantly, Shang et al. (2022) found no evidence that older adults were more prevalent among online fraud victims than other age groups and instead highlighted the importance of understanding factors associated with susceptibility to fraud, including trust, cognitive factors, internet experience, and techniques used by fraudsters. Thus, the findings of the present review suggest that cybersecurity risks among older adults should be understood not only in terms of the attacks encountered but also in relation to the deceptive strategies through which these attacks are carried out.

Regarding RQ3, the findings indicate that older adults do not adopt security practices uniformly. Rather than pointing to a single dominant protective behaviour, the reviewed studies reveal different patterns of cybersecurity behaviour that appear to depend strongly on digital literacy and access to support. A particularly important finding is the gap between awareness and behaviour: knowing about cybersecurity risks does not necessarily lead to the consistent adoption of recommended security practices. For some older adults, protection may even take the form of avoiding digital services or relying on family members rather than independently applying technical security measures. This suggests that cybersecurity awareness should not be equated with cybersecurity behaviour and that knowledge alone may be insufficient to ensure safe digital participation.

Regarding RQ4, the findings do not provide sufficient evidence to determine which type of cybersecurity awareness programme is most effective for older adults. The central issue is not the absence of proposed educational approaches, but the limited empirical evaluation of their effectiveness. In particular, the lack of direct comparisons and standardised outcome measures makes it difficult to establish whether one approach produces better or more sustainable outcomes than another. The findings therefore point to a gap between the development of cybersecurity education for older adults and the evidence available to demonstrate its effectiveness. Consequently, existing approaches should be regarded as promising rather than demonstrably effective, and stronger empirical evaluation is needed before firm conclusions about their comparative effectiveness can be drawn.

This review has several limitations that should be considered when interpreting its findings. First, the literature search was restricted to three databases (IEEE Xplore, Web of Science, and Scopus) and to English-language publications from 2020 to 2025. Relevant studies published in other languages, outside this time period, or indexed in other databases may therefore not have been captured. Second, the final synthesis included 14 studies, which limits the breadth of the available evidence. Finally, considerable heterogeneity in study designs, samples, and approaches to measuring cybersecurity awareness and behaviour limited direct comparison across studies and precluded stronger conclusions regarding particular security practices and the effectiveness of educational interventions. These limitations indicate that the findings of this review should be interpreted as a synthesis of the currently identified evidence rather than as a comprehensive representation of all research on cybersecurity awareness among older adults.

6 CONCLUSION

In conclusion, this systematic review demonstrates that cybersecurity awareness among older adults should not be understood primarily as a function of chronological age. Rather, it reflects the interaction of digital skills, education, access to support, life circumstances, and individual experience with technology. The findings therefore reinforce the importance of recognising older adults as a heterogeneous population with different levels of cybersecurity competence and different support needs.

The review further shows that cybersecurity vulnerability is shaped not only by exposure to particular cyber threats but also by the deceptive and psychologically manipulative strategies through which many attacks operate. At the same time, awareness of such risks does not necessarily translate into protective behaviour. The identified gap between cybersecurity awareness and actual security practices suggests that increasing knowledge alone may be insufficient to ensure safe and independent digital participation among older adults.

With regard to cybersecurity education, the available evidence does not yet support firm conclusions about which interventions are most effective. Practical, socially supported, and individually tailored approaches appear promising, but the limited number of empirical evaluations and the lack of standardised outcome measures make comparisons between interventions difficult. Future research should therefore prioritise the systematic and longitudinal evaluation of cybersecurity interventions, using comparable outcome measures and taking into account differences in digital skills and access to support among older adults.

Overall, improving cybersecurity among older adults requires an approach that extends beyond individual responsibility and combines appropriate education with accessible support and age-sensitive digital environments. Such an approach may contribute to safer and more confident digital participation while reducing the risk that cybersecurity concerns themselves become a barrier to digital inclusion.

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1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

CONVOLUTIONAL NEURAL NETWORK FOR PNEUMONIA DETECTION IN CHEST X-RAY IMAGES

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ABSTRACT

Diagnosing pneumonia from chest X-rays has great potential using convolutional neural networks (CNNs), but high overall accuracy can hide serious problems with specific classes when data is imbalanced. In this study, we developed and tested a compact CNN to classify pediatric chest X-rays as normal or showing pneumonia, prioritising efficiency and transparent reporting of failure modes.

We used the Kaggle Chest X-ray Images (Pneumonia) dataset (5,856 images from Guangzhou Women and Children's Medical Centre), split into 3,279 training (56%), 1,405 validation (24%), and 1,172 test images (20%). Images were resized to 64 × 64 pixels, rescaled, and augmented only during training. The CNN has 151,762 parameters, combining two convolutional blocks, batch normalisation, max pooling, a sixteen-unit dense layer, dropout, and a SoftMax output. Training used Adam (learning rate 0.0001), batch size 32, class weighting, early stopping, and learning-rate reduction. An intermediate configuration achieved 92.41% test accuracy. However, increasing dropout to 0.5 and adding L2 regularisation collapsed performance to 72.95% accuracy, with 73.07% precision, 99.65% recall, but only 0.95% specificity and an F1-score of 0.8431. The confusion matrix showed the model correctly classified just three normal images while misclassifying 314, revealing that despite a strong recall and encouraging training curves, it behaved like a majority-class classifier. This study highlights the necessity of confusion matrices, specificity, and other class-specific metrics when evaluating medical classifiers, since aggregate accuracy alone can conceal near-total failure on the minority class. The final model is not suitable for clinical use. We recommend incrementally tuning regularisation, running multiple training seeds, comparing against transfer-learning approaches, and validating models on external datasets before any deployment claim is made.

Keywords: *pneumonia detection, convolutional neural networks, lightweight architecture, class imbalance, confusion matrix*

1 INTRODUCTION

Pneumonia remains a major cause of mortality, while chest X-ray radiography remains a primary diagnostic imaging modality because it is accessible and comparatively inexpensive (Szepesi and Szilágyi 2022, 1012; Nguyen-Tat et al. 2025, 4). Manual interpretation is time-consuming and places pressure on health systems with limited specialist capacity, particularly in rural and resource-constrained settings (Hariri and Avşar 2023, 1; Sharma and Guleria 2023, 357–358). CNNs may support radiologists by learning spatial features directly from images and producing rapid, repeatable classifications (Mienye et al. 2025, 1; Robinson et al. 2024, 1).

Published CNN studies often report accuracy above 90%, including compact models intended for limited computing environments (Hariri and Avşar 2023, 1; Prakash and Ramamurthy 2024, 369). Nevertheless, accuracy is prevalence-sensitive and can appear acceptable when a classifier predicts the majority class almost exclusively. The specific gap addressed here is therefore not merely whether a small custom CNN can attain a competitive aggregate score, but whether it can do so while preserving discrimination between normal and pneumonia images. The contribution is a transparent, reproducible account of a 151,762-parameter model across successive configurations, including a negative final experiment in which stronger regularisation produced superficially plausible accuracy but near-zero specificity. This failure analysis is particularly relevant to low-resource deployment, where compact models must be evaluated with more than one headline metric.

The study asks whether a lightweight CNN trained from scratch can distinguish normal from pneumonia radiographs on a held-out test set and how augmentation, batch normalisation, dropout, class weighting, and L2 regularisation influence that behaviour. It evaluates accuracy, precision, recall, specificity, F1-score, training curves, and the confusion matrix. The model is treated as an experimental classifier rather than a clinical diagnostic device.

2 LITERATURE REVIEW

2.1 CNN architectures for pneumonia detection

CNNs learn hierarchical visual features by combining convolution, nonlinear activation, pooling, and fully connected classification layers (Mienye et al. 2025, 1). Transfer-learning systems reuse representations learned from large image collections, whereas custom CNNs can be designed with fewer parameters for a narrower task. Sharma and Guleria (2023, 361) reported 92.15% accuracy using VGG16 as a pretrained feature extractor. Szepesi and Szilágyi (2022, 1017) placed dropout within convolutional components and achieved 97.21% ± 1.13% accuracy through tenfold cross-validation. Hariri and Avşar (2023, 9, 12) obtained 89.89% accuracy for a harder four-class task with a 1,043,558-parameter model, while Prakash and Ramamurthy (2024, 371, 375) combined texture features with a fully convolutional network to reach 97% test accuracy. Alam et al. (2024, 4169) reported 97.24% using depthwise separable and inverse-residual components.

2.2 Custom models, transfer learning, and generalisation

Comparative findings are mixed. Cakra et al. (2026, 1899) found ResNet50 more accurate than VGG16 and a custom CNN, while Billah et al. (2024, 5) similarly placed ResNet50V2 ahead of VGG16 and InceptionV3. Maquen-Niño et al. (2024, 156) reported 91.35% for ResNet50V2, compared with 87.82% for DenseNet and 86.86% for VGG19. By contrast, Senanayake et al. (2025, sec. IV) found a six-layer custom CNN advantageous when only 100 to 500 images were available, and Vyas and Mehta (2025) reported a custom model outperforming several pretrained alternatives. Al-Azzawi et al. (2025, 20481) and Dahmane et al. (2021, 1477) also obtained strong results from purpose-built or hybrid architectures. Dataset scale, optimisation, preprocessing, and evaluation design therefore limit direct architectural comparisons (Romero et al. 2019, 20).

External validation remains a more demanding test than an internal split. Khasawneh et al. (2021, 9–11) observed a marked reduction in custom-CNN accuracy on a locally collected cohort, while pretrained alternatives degraded less. Domain-specific pretraining may also matter: Mahajan et al. (2019, 5) found CheXNet-pretrained weights more effective than ImageNet-pretrained weights. En-

semble approaches can raise internal performance further; Kundu et al. (2021, 1) and Mujahid et al. (2022, 11) reported high accuracies from combinations of established architectures. Such results do not remove the need for per-class analysis, especially when class frequencies differ.

Transfer learning and custom design also differ in their computational trade-offs. A pretrained network may reduce the amount of task-specific representation learning required, but its parameter count, memory footprint, and inference cost may exceed what is practical on modest hardware. A custom network can reduce these requirements by limiting convolutional depth and dense-layer width, although reduced capacity may make results more sensitive to preprocessing, initialisation, and regularisation. El Asnaoui et al. (2020, 277–278) reported a large advantage for ResNet50 over both VGG19 and a custom CNN, whereas the limited-data experiments of Senanayake et al. (2025, sec. IV) favoured a compact design. These apparently conflicting findings reinforce the need to compare models under identical data partitions and evaluation measures rather than transferring performance claims between studies.

Architecture alone also does not determine performance. Harahap et al. (2022, 76) found ResNet50V2 more accurate than VGG19 in a related chest X-ray classification problem, while Rida and Rahardi (2025, 2174–2175) reported stronger results for DenseNet121 than ResNet50 on both internal and external test sets. These studies suggest that feature reuse, connectivity pattern, fine-tuning depth, and domain similarity interact. For the present study, the relevant question is narrower: whether a very small network can preserve both sensitivity and specificity after training adjustments. This focus makes a transparent negative result valuable because it identifies a boundary condition for model efficiency.

2.3 Evaluation and unresolved challenges

The Kaggle dataset used in this study contains paediatric anterior-posterior radiographs from Guangzhou Women and Children's Medical Centre and has been used by Sharma and Guleria (2023, 360) and Szepesi and Szilágyi (2022, 1013–1014). Its class imbalance makes accuracy insufficient on its own. Precision describes the proportion of predicted pneumonia cases that are correct; recall describes the proportion of pneumonia cases detected; specificity measures recognition of normal cases; and F1 combines precision and recall. Mienye et al. (2025, 3) emphasise comprehensive metric reporting, while Szepesi and Szilágyi (2022, 1017) illustrate the value of cross-validated accuracy, precision, and recall. Interpretability and demographic generalisation remain unresolved, and Prakash and Ramamurthy (2024, 375) used Gradient-weighted Class Activation Mapping to examine whether relevant anatomical regions informed predictions.

Class imbalance has different consequences for different errors. In a pneumonia-screening context, false negatives may delay treatment, whereas false positives can trigger unnecessary follow-up, anxiety, workload, and resource use. A model with extremely high pneumonia recall but negligible specificity does not provide a useful trade-off; it reproduces the decision rule "treat nearly every image as positive." Macro-averaged metrics give equal weight to the two classes and can therefore expose this imbalance more clearly than weighted averages. Confusion matrices retain the underlying error counts and allow readers to verify every reported measure. These considerations motivated the reporting strategy used in this study.

Dataset provenance and split construction are equally important. Studies using the same named collection can report different numbers if they retain its original highly uneven folders, omit corrupt files, or recombine the directories before splitting. A stratified re-split preserves the observed class proportion across training, validation, and test subsets and avoids a test set dominated by a single class folder. Nevertheless, patient-level independence cannot be verified from directory-level filenames alone, and an image-level random split cannot exclude every form of source correlation. This limitation should be kept in mind when internal test performance is compared with external clinical evidence.

The literature therefore establishes strong benchmark performance but also shows that model size, task complexity, data volume, and validation design vary substantially. The present study does not claim superiority over transfer learning. It tests a compact architecture and makes its failure mode visible through a held-out two-class test set and a full confusion matrix.

3 METHODOLOGY

3.1 Dataset and split

The study used only the public Chest X-ray Images (Pneumonia) dataset distributed on Kaggle (https://www.kaggle.com/datasets/paultimothymooney/chest-xray-pneumonia). The 5,856 anterior-posterior images originate from paediatric patients aged one to five years at Guangzhou Women and Children's Medical Centre. Files from the original directories were pooled, labelled normal (0) or pneumonia (1), and stratified with random seed 42. A first split assigned 56% to training and 44% to a temporary set; the latter was divided to produce 24% validation and 20% test allocations. This procedure reconciles the manuscript and notebook totals shown in Table 1.

Table 1: Stratified data allocation (N = 5,856)

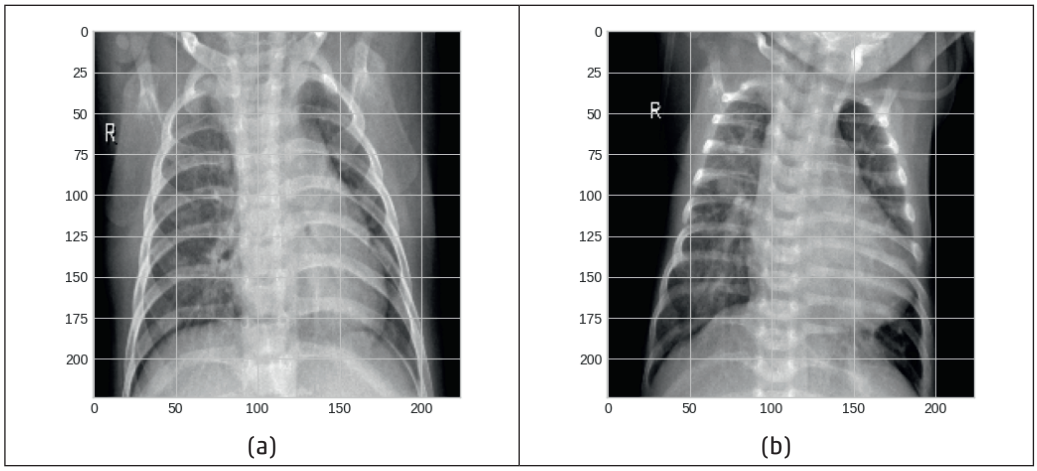
Subset	Images	Percentage
Training	3,279	56%
Validation	1,405	24%
Test	1,172	20%

(Source: Author's own work)

3.2 Preprocessing and augmentation

Images were loaded as RGB inputs, resized to 64 × 64 pixels, and rescaled by 1/255. Training data alone were augmented through rotations up to 20 degrees, horizontal and vertical shifts of 15%, zoom up to 15%, horizontal flipping, and nearest-pixel filling. Validation and test images were only rescaled, ensuring that evaluation used unmodified images. Batch size was 32. Figure 1 shows representative images retained from the exploratory analysis.

Figure 1: Representative input images: (a) normal and (b) pneumonia.



(Source: Author's own work based on Guangzhou Women and Children's Medical Centre data set)

3.3 Architecture and training

The Sequential CNN accepted 64 × 64 × 3 inputs. The first block applied 64 same-padded 3 × 3 filters, batch normalisation, ReLU activation, and 2 × 2 max pooling. The second used 32 same-padded 3 × 3 filters followed by the same normalisation, activation, and pooling sequence. Flattening produced 8,192 values, which fed a sixteen-unit ReLU layer and a two-unit SoftMax output. He-normal initialisation was used for ReLU layers. Table 2 converts the notebook model summary into a typeset table, correcting the earlier "CCN" caption. The architecture contained 151,762 parameters: 151,570 trainable and 192 non-trainable batch-normalisation parameters.

Table 2: CNN architecture and parameter counts

Layer	Output shape	Parameters
Conv2D, 64 filters	64 × 64 × 64	1,792
Batch normalisation	64 × 64 × 64	256
Max pooling	32 × 32 × 64	0
Conv2D, 32 filters	32 × 32 × 32	18,464
Batch normalisation	32 × 32 × 32	128
Max pooling	16 × 16 × 32	0
Flatten	8,192	0
Dense, 16 units	16	131,088
Dropout	16	0
Dense, 2 units	2	34
Total		151,762

(Source: Author's own work based on Guangzhou Women and Children's Medical Centre data set)

Training used Adam with an initial learning rate of 0.0001, categorical cross-entropy, class weights of 1.8505 for normal and 0.6851 for pneumonia, and a maximum of 29 epochs. Early stopping monitored validation loss with patience of eight epochs and restored the best weights. ReduceLROnPlateau halved the learning rate after four epochs without improvement. Runs were executed in Google Colab; the notebook did not record the accelerator model, which limits hardware-level reproducibility. The first stabilised configuration used dropout of 0.3 without L2 regularisation. A subsequent experiment increased dropout to 0.5 and applied L2 = 0.001 to convolutional and dense kernels. The supplied new training curves and confusion matrix refer to this later configuration, which trained for eight epochs before evaluation.

The experimental sequence was interpreted as configuration testing rather than as a formal ablation study. The original baseline used a higher learning rate, no augmentation, and no batch normalisation and collapsed to the majority class. The stabilised intermediate run changed several elements together and produced balanced held-out results. The final run retained augmentation, batch normalisation, class weighting, and the lower learning rate, but strengthened regularisation through higher dropout and L2 penalties. Because multiple changes occurred between the baseline and intermediate run, their individual effects cannot be estimated. Because dropout and L2 changed together in the final run, their separate effects also remain unidentified. Reporting all three stages prevents selective presentation of the strongest run while keeping causal claims appropriately limited.

Random seed 42 controlled the stratified file allocation and generator shuffling where specified. The test generator used shuffle=False so that predicted probabilities remained aligned with the stored class labels. SoftMax probabilities were converted to class predictions with argmax. The confusion matrix used the fixed label order normal then pneumonia, allowing its four cells to be interpreted consistently as true negatives, false positives, false negatives, and true positives with pneumonia designated as the positive class.

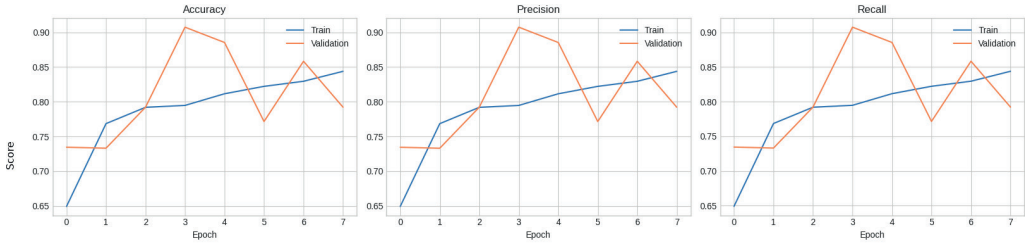
3.4 Performance measures

For true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN), accuracy = (TP + TN)/(TP + TN + FP + FN); pneumonia precision = TP/(TP + FP); recall or sensitivity = TP/(TP + FN); specificity = TN/(TN + FP); and F1 = 2 × (precision × recall)/(precision + recall). Categorical cross-entropy measured optimisation loss. Metrics were calculated on the 1,172-image held-out test set containing 317 normal and 855 pneumonia images. Because a majority-class classifier can score approximately 73% accuracy on this test set, conclusions prioritised specificity and the confusion matrix alongside accuracy, precision, recall, and F1.

4 RESULTS

The stabilised intermediate configuration, using dropout 0.3 without L2 regularisation, avoided the initial collapse and produced 92.41% test accuracy, 97.28% precision, 92.16% recall, 93.06% specificity, and an F1-score of 0.9465. This result established that the small architecture could learn both classes under one training configuration. The later experiment then increased dropout to 0.5 and added L2 regularisation to all convolutional and dense kernels. Figure 2 presents the requested training and validation curves from that final run.

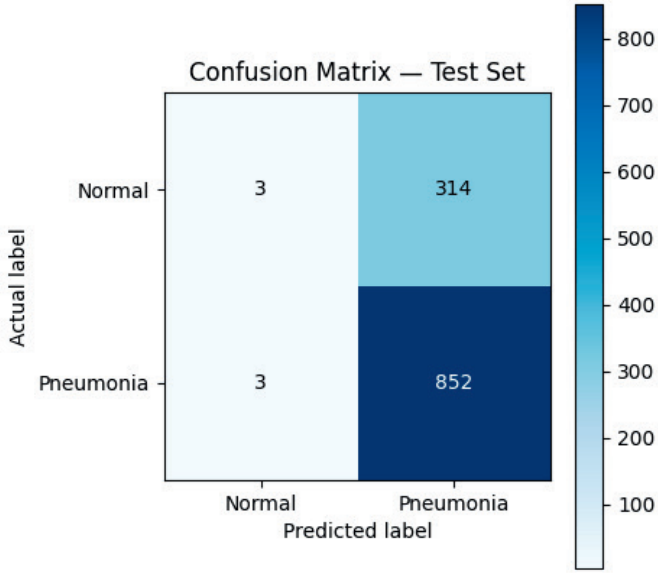
Figure 2: Training and validation accuracy, precision, and recall across eight epochs for the final dropout-plus-L2 experiment. The x-axes show epoch number and the y-axes show the corresponding metric.



(Source: Author's own work)

Training accuracy, precision, and recall increased from approximately 0.65 at epoch 1 to 0.84 at epoch 8. Validation measures were more volatile: they were approximately 0.73 for the first two epochs, reached 0.91 at epoch 4, fell to 0.77 at epoch 6, recovered to 0.86 at epoch 7, and ended at 0.79. Because Keras categorical precision and recall were calculated over one-hot outputs in this run, the three plotted validation series are numerically identical to validation accuracy and do not replace class-specific evaluation. The divergence and volatility after epoch 4 indicate unstable generalisation rather than steady convergence.

Figure 3: Confusion matrix for the held-out test set after the final dropout-plus-L2 experiment (n = 1,172). Rows are actual classes and columns are predicted classes.



(Source: Author's own visualization)

Figure 3 shows three true negatives, 314 false positives, three false negatives, and 852 true positives. The model predicted pneumonia for 1,166 of 1,172 images. Consequently, its 72.95% accuracy was almost identical to the pneumonia prevalence in the test set (72.95%). Pneumonia recall was 99.65%, but specificity was only 0.95%; only three of 317 normal images were recognised. Table 3 summarises the metrics derived directly from the supplied confusion matrix.

Table 3: Held-out test performance for the final dropout-plus-L2 experiment.

Metric	Value
Accuracy	72.95%
Pneumonia precision	73.07%
Pneumonia recall (sensitivity)	99.65%
Specificity	0.95%
Pneumonia F1-score	0.8431
Normal-class F1-score	0.02
Macro-average F1-score	0.43

(Source: Author's own work)

5 DISCUSSION

The final experiment demonstrates why overall accuracy and pneumonia recall cannot independently establish clinical usefulness. A classifier predicting almost every image as pneumonia necessarily identifies nearly every true pneumonia case, producing 99.65% recall, yet it also sends almost every normal image into the positive class. The resulting 0.95% specificity and 314 false positives make the model unsuitable for screening or decision support. Its 72.95% accuracy is not evidence of learned discrimination because it matches the test set's pneumonia base rate. The confusion matrix therefore changes the interpretation of the training curves: although validation measures briefly reached 0.91, the held-out predictions reveal collapse.

The comparison between configurations provides a more informative result than the final aggregate score alone. Batch normalisation, training-only augmentation, class weighting, a lower learning rate, and dropout of 0.3 produced an intermediate model with balanced test performance. Increasing dropout to 0.5 while simultaneously adding L2 = 0.001 removed that balance. A plausible interpretation is that compounded regularisation constrained an already narrow sixteen-unit dense representation too strongly, making the majority-class solution easier to retain. This remains an inference because dropout and L2 were changed together rather than in a factorial experiment. The study therefore cannot isolate which component, or interaction between them, caused the deterioration.

The negative result also qualifies comparisons with the literature. Szepesi and Szilágyi (2022, 1017) achieved 97.21% ± 1.13% accuracy using tenfold cross-validation and strategically located dropout. Prakash and Ramamurthy (2024, 371, 375) reported 97% after adding texture information, while Hariri and Avşar (2023, 7, 12) reported 89.89% on a four-class task with extensive augmentation. The intermediate configuration's 92.41% accuracy falls within this broad range, but the final configuration clearly does not exhibit comparable balanced performance. Moreover, the tasks, splits, validation procedures, and model sizes differ, so numerical rankings would be inappropriate. The strongest contribution here is transparency about instability in a compact model rather than a claim of state-of-the-art diagnosis.

Hariri and Avşar's (2023, 6–7) four-class problem includes distinctions that are absent from binary classification, while their augmentation substantially expanded minority categories. Szepesi and Szilágyi (2022, 1017) used repeated folds, which provides evidence across partitions rather than one test allocation. Prakash and Ramamurthy (2024, 370–371) supplied engineered texture information in addition to learned image features. The present network uses lower-resolution RGB inputs and only two convolutional blocks. These design differences help explain why the cited figures should be used as context, not as a direct leaderboard. They also identify concrete avenues for testing whether the lightweight design can be improved without recreating the majority-class failure.

The final confusion matrix offers an additional lesson about validation volatility. The peak validation value at epoch 4 could encourage selection of that epoch as evidence of improvement, yet the later held-out predictions were severely imbalanced. Validation fluctuations may reflect the interaction of augmentation, class weighting, limited model capacity, and strong regularisation. Repeating the run with several seeds would show whether the collapse is systematic or stochastic. Recording class-specific validation confusion matrices at each epoch would reveal when normal-class recognition deteriorates and would support checkpointing against a prespecified specificity threshold.

The distinction between the intermediate and final configurations is also important for scientific reporting. Presenting only the intermediate run would suggest that the modelling problem had been solved, while presenting only the final run would obscure evidence that the architecture can learn a balanced boundary under less aggressive regularisation. Reporting both demonstrates configuration sensitivity and separates architectural capacity from optimisation outcome. The intermediate metrics should still be treated cautiously because they derive from a single run, but they provide a testable baseline for subsequent experiments. A rigorous follow-up could hold the data split, seed, optimiser, augmentation, and class weights constant while varying dropout across a small grid, then repeat the procedure for L2 strength. Only after identifying stable ranges separately should both methods be combined. Each candidate should be compared using balanced accuracy, macro-F1, specificity, and calibration in addition to pneumonia recall. Confidence intervals obtained by bootstrap resampling of the held-out predictions would quantify sampling uncertainty, while repeated training would quantify optimisation variability. This design would determine whether the collapse reflects excessive regularisation, an unlucky training trajectory, or an interaction between the two. It would also provide a more defensible basis for selecting a compact model than choosing the epoch or configuration with the highest observed validation accuracy. In a clinical workflow, threshold analysis would be required as well: SoftMax argmax fixes an implicit decision threshold, whereas sensitivity and specificity can be traded deliberately. Receiver-operating and precision-recall curves could characterise that trade-off, but threshold selection must remain separate from final test evaluation to avoid optimistic bias.

This staged evaluation also supports reproducibility because future researchers can reconstruct each decision from the notebook, compare configurations against identical test labels, and determine whether proposed remedies improve both classes rather than only aggregate performance.

The findings support comprehensive reporting recommended in the reviewed work (Mienye et al. 2025, 3). Precision and recall should be class-specific, because the categorical Keras metrics plotted during training were identical to accuracy for the one-hot two-class outputs. In imbalanced medical data, specificity, per-class recall, macro-averaged scores, and the confusion matrix reveal errors that a weighted or global measure can obscure. Monitoring a single validation loss also did not guarantee a balanced final classifier. Checkpoint selection should therefore incorporate a class-sensitive criterion such as balanced accuracy, macro-F1, or minimum acceptable specificity, followed by evaluation on an untouched test set.

From a resource perspective, the 151,762-parameter architecture remains attractive, but parameter efficiency is only meaningful after discrimination and generalisation are demonstrated. Senanayake et al. (2025, sec. V) showed that custom models can be advantageous with limited data, whereas Cakra et al. (2026, 1899), Billah et al. (2024, 5), and Maquen-Niño et al. (2024, 156) found strong transfer-learning baselines. A direct comparison under the same split is required before claiming a computational advantage. External validation is equally important because Khasawneh et al. (2021, 9) documented substantial performance degradation outside the training source. The single-institution paediatric cohort used here cannot establish applicability to adults, other regions, or different acquisition equipment.

Computational efficiency should also be measured rather than inferred solely from parameter count. Future comparisons should record model size on disk, peak memory use, inference latency, throughput, and energy use on the intended edge hardware. A small parameter total may still incur nontrivial activation memory, and resizing to 64 × 64 may remove subtle radiographic information. Conversely, a larger pretrained backbone may be compressed or quantised. The present study establishes architectural compactness, but it does not yet establish end-to-end deployment efficiency.

5.1 Limitations

The analysis used one stratified split and one recorded run per configuration; uncertainty across seeds and confidence intervals were not estimated. The dataset is imbalanced and represents children aged one to five years from one institution. No external cohort, adult population, transfer-learning baseline, calibration assessment, or explainability analysis was included. Hyperparameters were adjusted iteratively rather than through a prespecified search, and dropout and L2 were changed simultaneously in the final experiment. The notebook records Google Colab as the platform but not the precise CPU, GPU, memory, TensorFlow version, or execution date. Finally, the apparent equality of categorical accuracy, precision, and recall in the training curves limits their class-specific interpretability. These limitations prevent clinical claims and restrict the study to a methodological proof of concept and failure analysis.

6 CONCLUSION

This study evaluated a lightweight CNN for binary pneumonia classification and incorporated the complete held-out test set, class-specific metrics, new training curves, and the requested confusion matrix. The stratified 56%/24%/20% split contained 3,279 training, 1,405 validation, and 1,172 test images. A stabilised intermediate configuration showed that the compact architecture could achieve balanced performance, but the final experiment combining dropout of 0.5 with L2 regularisation collapsed toward the pneumonia majority class. It achieved 72.95% accuracy and 99.65% pneumonia recall while recognising only three of 317 normal images, yielding 0.95% specificity. The final model is therefore not suitable for clinical deployment.

The main implication is methodological: lightweight medical classifiers must be evaluated with confusion matrices, specificity, and per-class measures, and hyperparameter changes must be introduced incrementally. Future work should vary dropout and L2 separately, use repeated stratified runs or cross-validation, select checkpoints with class-sensitive criteria, compare the same split against ResNet50V2 and DenseNet121, assess calibration, and validate on external adult and paediatric cohorts. Gradient-weighted Class Activation Mapping may then test whether predictions depend on relevant anatomical regions, as demonstrated by Prakash and Ramamurthy (2024, 375). Until those steps are completed, the model should be presented as an informative compact-CNN experiment rather than a diagnostic system.

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1.08 Objavljeni znanstveni prispevek na konferenci
Published scientific conference contribution

AI-DRIVEN NETWORK SLICING IN 6G: REGULATORY REQUIREMENTS AND EXPLAINABILITY BY AI TECHNIQUES

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ABSTRACT

The advent of 6G networks introduces capabilities such as ultra-low latency, massive data rates, and ubiquitous intelligence, demanding a paradigm shift from traditional static spectrum allocation to dynamic AI-driven management. Network slicing, a cornerstone technology inherited from 5G, enables the creation of virtual, isolated networks on shared physical infrastructure to deliver tailored services supporting diverse use cases, including enhanced Mobile Broadband (eMBB), ultra-Reliable Low-Latency Communication (URLLC), and massive Machine-Type Communication (mMTC). However, the proliferation of slices exacerbates challenges in resource orchestration, spectrum efficiency, and real-time adaptation amid fluctuating demands and interference. Artificial Intelligence (AI), particularly Machine Learning (ML), emerges as a core enabler of network slicing in 6G. AI techniques facilitate dynamic allocation, predictive analytics, adaptive policies, topological optimization, and orchestration, enhancing efficiency and supporting autonomous operations. Despite these advancements, the opacity of AI systems raises critical concerns regarding transparency, fairness in resource allocation, equity of access, and regulatory oversight. This paper examines the hypothesis that distinct AI algorithms for network slicing necessitate tailored explanations to address equity and governance issues. Through qualitative prescriptive analysis of related standards of ETSI, including technical feasibility, alongside a literature review, the study evaluates how various AI techniques align with regulatory principles, including the proposed Digital Networks Act (DNA) obligations for obligatory spectrum sharing (intra- and inter-service), usage priority, coexistence rules, interference protection, and dynamic geolocation databases. Findings highlight that, although many AI methods meet core DNA and ETSI Zero-touch Service Management requirements for service discovery, invocation, and communication, challenges persist in real-time data quality, unbiased access, explainability, and timeliness—particularly for complex models such as DRL, FL, and LLMs. The research proposes an objective regulatory framework to ensure equitable spectrum access, non-discriminatory prioritization, and efficient real-time data utilization, bridging technical AI capabilities with legal imperatives for fair, transparent 6G deployment.

Keywords: *AI-enabled network slicing, 6G networks, regulatory framework, radio frequency spectrum management*

1 INTRODUCTION

The advent of Sixth-Generation (6G) networks promises unprecedented capabilities, including ultra-low latency, massive data rates, and ubiquitous intelligence, necessitating a fundamental rethinking of network management paradigms (Chataut et al. 2024, Thabet et al. 2025, Aygül 2025, Wei et al. 2020). Traditional static spectrum allocation and network resource management are insufficient for the dynamic and heterogeneous demands of future networks (Bushra et al. 2024, Gbenga-Ilori et al. 2025, Onaji et al. 2025, Alcalá-Marín 2025, Thomatos et al. 2025). Network slicing is an established technology that allows service providers to create virtual networks, commonly referred to as „slices", to offer customized services, with unique characteristics and policies, such as different levels of bandwidth and reliability, or types of traffic. Network slicing creates multiple virtual networks on a single physical network layer, that is, within a radio frequency band or set of channels. Beyond the multilateral benefits of network slicing for dynamic spectrum sharing, management, and orchestration challenges remain as the number of slices increases; consequently, allocating network resources across multiple slices becomes complex and time-consuming. Automating this process with AI/ML algorithms is a logical next step (El Rajab et al. 2024). According to 3GPP, network slicing enables multiple virtual end-to-end network instances to operate on a shared physical infrastructure while maintaining logical isolation between tenants and services. Although this approach improves spectrum utilisation and service flexibility, increasing numbers of slices create significant challenges for resource allocation, orchestration, and management, making AI-enabled automation a necessary evolution for future 6G networks (El Rajab et al. 2024).

Artificial Intelligence (AI) is emerging as a core enabler of 6G networks, supporting both dynamic spectrum management and AI-enabled network slicing through predictive analytics, adaptive resource allocation, and autonomous decision-making (Raheem et al. 2025, Chataut et al. 2024). By continuously adapting to changing demand and interference conditions, AI improves spectrum efficiency, service quality, and operational automation across heterogeneous wireless environments (Bushra et al. 2024, Gbenga-Ilori et al. 2025, Alhammadi et al. 2024).

Despite these technological advances, the opacity of AI systems raises concerns regarding transparency, fairness, and regulatory oversight. Consequently, Explainable AI (XAI) is increasingly regarded as a prerequisite for trustworthy and accountable autonomous 6G systems, particularly where equitable access to spectrum and network resources must be ensured (Raheem et al. 2025, Ali 2025).

Effective AI-enabled network slicing requires cooperation among communication service providers, including standardised data exchange, interoperable management processes, and trust mechanisms for cross-domain operation. These requirements become even more important as networks evolve toward highly automated and autonomous 6G environments.

The proposed Digital Networks Act (DNA) introduces mandatory spectrum-sharing obligations among operators and establishes requirements related to usage priority, coexistence rules, interference protection, and dynamic geolocation databases. These provisions represent a significant shift from traditional spectrum governance and create new compliance requirements for AI-enabled network slicing and autonomous spectrum management.

While previous research has primarily focused on the technical optimisation, orchestration, and performance benefits of AI-enabled network slicing, comparatively little attention has been paid to the regulatory implications of different AI techniques in spectrum-sharing environments. Moreover, the relationship between AI explainability, equitable spectrum access, and emerging European regulatory requirements remains insufficiently explored. This study addresses this research gap by providing a structured regulatory-technical assessment of the principal AI techniques used in network slicing against the requirements of the proposed Digital Networks Act and ETSI Zero-touch Service Management standards.

Given the issues mentioned earlier, a paradigm shift is evident and must be accompanied by an innovative regulatory framework.

2 PURPOSE AND GOALS

This research paper tests the hypothesis that different algorithms used in AI-driven network slicing in 6G wireless networks require distinct approaches and an XAI solution to address equity and governance issues. Whether the hypothesis is confirmed or not, this resonance constitutes a new regulatory scheme that encompasses not only the efficient use of the radio spectrum but also usage priority, usage type, and a dynamic database to achieve the goals.

A new regulatory approach, accompanied by a newly proposed objective framework for distinct AI-driven network slicing algorithms, should contribute to equal access, avoid non-objective prioritisation, and leverage the most efficient and effective database of real-time data. There are no common standards for measuring AI-enabled network slicing with respect to data collection, sharing, and processing; consequently, equity of access remains an abstract goal rather than being embodied in real-time data processing. The aim of this paper is to conduct ground research.

3 METHODS

3.1 Methodology

The method that best serves the goals and purpose of the main research question is qualitative, using the Better Regulation framework and technical feasibility. The research question is based on "how" and "what". The proposed qualitative research method will be a prescriptive analysis (i.e., what should be done and the best course) to better ensure equitable spectrum access in the context of AI-enabled network slicing across different operators and users. The prescriptive scale will be the Better Regulation Guidelines and Toolbox (European Commission 2021), such as fit-for-purpose, which is not aligned with the described goals of regulatory frameworks: effectiveness, efficiency, coherence, and strategic foresight. The qualitative assessment also incorporates relevant ETSI standards, but they are intended for network slicing rather than AI-enabled network slicing

This qualitative prescriptive method should improve understanding of equitable spectrum access from a regulatory perspective, including technical knowledge. The proposed research is interdisciplinary, focusing on the technical background of AI applications and on various yet suboptimal legal and regulatory frameworks. A complementary research approach from both regulatory/legal and AI-technical perspectives is long overdue.

3.2 Assessment Framework

To systematically evaluate the suitability of AI techniques for AI-enabled network slicing under emerging spectrum-sharing obligations, a qualitative regulatory-technical assessment framework was developed. The framework combines principles of the European Commission Better Regulation Guidelines with the operational requirements contained in the proposed Digital Networks Act (DNA) and the ETSI Zero-touch Service Management (ZSM) framework. The objective was to determine whether different AI techniques provide sufficient technical and governance capabilities to support equitable, transparent, and efficient spectrum sharing in future 6G environments. The assessment was conducted using four Better Regulation criteria: **effectiveness**, **efficiency**, **coherence**, and **fit-for-purpose**. Effectiveness refers to the ability of an AI technique to support regulatory objectives related to equitable spectrum access and resource allocation. Efficiency assesses whether the technique can perform the required functions with acceptable computational and operational overhead. Coherence evaluates the compatibility of the AI technique with existing telecommunications and AI governance frameworks. Finally, fit-for-purpose examines whether the technique is suitable for the specific requirements of AI-enabled network slicing and dynamic spectrum management.

The regulatory assessment grid was derived from the proposed Digital Networks Act and included four key requirements: (1) support for usage priority mechanisms, (2) enforcement of coexistence rules between spectrum users, (3) protection against harmful interference, and (4) utilisation of dynamic geolocation databases for spectrum-sharing opportunities. In addition, four ETSI ZSM capabilities were considered: service discovery, service registration, service invocation, and support for synchronous and asynchronous communication across domains.

Seven AI techniques were selected for assessment based on their recurrent appearance in recent scientific literature on AI-enabled network slicing and autonomous network management: Machine Learning (ML), Deep Learning (DL), Reinforcement Learning (RL), Deep Reinforcement Learning (DRL), Federated Learning (FL), Graph Neural Networks (GNNs), and Large Language Models (LLMs). For each technique, evidence concerning functionality, decision-making processes, data requirements, explainability, and operational constraints was extracted from the reviewed literature and compared against the assessment criteria.

The outcome of the assessment is not intended to provide a quantitative ranking of AI techniques. Rather, it identifies areas where specific technologies are more or less capable of supporting regulatory objectives related to equitable spectrum sharing, transparency, explainability, and real-time decision-making in AI-enabled 6G network slicing environments. These findings form the basis of the regulatory recommendations presented in the Results and Discussion sections. Table 1 summarises the assessment criteria and their respective sources.

Table 1: Regulatory-Technical Assessment Criteria

Criterion	Source
Effectiveness	Better Regulation Guidelines
Efficiency	Better Regulation Guidelines
Coherence	Better Regulation Guidelines
Fit-for-purpose	Better Regulation Guidelines
Usage priority	DNA
Coexistence rules	DNA
Harmful interference protection	DNA
Dynamic geolocation database	DNA
Service discovery	ETSI ZSM
Service registration	ETSI ZSM
Service invocation	ETSI ZSM
Synchronous/asynchronous communication	ETSI ZSM

(Source: Author's own work)

4 RESULTS

4.1 Overview of AI Techniques

Based on an exhaustive literature review, a wide range of AI techniques and systems are employed for AI-enabled network slicing and related automated network management tasks. These techniques are expected to further develop in 6G environments (El Rajab et al. 2024). These techniques range from traditional Machine Learning to advanced Large Language Models. This fact alone makes it challenging to place all the techniques used on the same regulatory footing, including with respect to equity of access.

Machine Learning (ML) uses statistical learning methods for prediction, classification, clustering, and resource optimisation in network slicing (Mekrache et al. 2024; Thomatos et al. 2025).

Deep Learning (DL) applies multi-layer neural networks to support predictive analytics and resource allocation (Alhammadi et al. 2024; Liang 2020).

Reinforcement Learning (RL) optimises network policies through reward-based learning and adaptive decision-making (Gbenga-Ilori et al. 2025; Liang 2020; Alhammadi et al. 2024; Salwadakar 2025).

Deep Reinforcement Learning (DRL) combines deep neural networks and reinforcement learning to support autonomous network optimisation (Boni 2025; Thomatos 2025; Salwadakar 2025).

Federated Learning (FL) enables distributed model training while preserving data privacy across participating entities (Chiarani et al. 2025; Salwadakar 2025; Alam et al. 2025).

Graph Neural Networks (GNNs) model network topology and relationships among interconnected network elements (González De Dios et al. 2025; Farreras et al. 2025)

Large Language Models (LLMs) support intent-based management and service orchestration through natural-language interaction (Dandoush et al. 2024).

4.2 Regulatory Assessment of AI Techniques

To enable AI-ready network slicing, the automation of connectivity provisioning and of monitoring and detecting quality degradation is essential. To share the radio frequency spectrum among independent holders, functional requirements for cross-domain service and integration access must be considered. According to the ETSI (European Telecommunications Standards Institute), in Zero-touch Network, as a step further toward network automation, the requirements for Cross-Domain Service integration and access include: 1) Enabling the discovery and registration of management services; 2. Providing information on accessing the discovered service 3. Invoke services indirectly or directly and 4. Support both synchronous and asynchronous communication between users (El Rajab et al. 2024). ETSI then continued the standardization and released the standard of Zero-touch network and Service Management (ZSM); End-to-end management and orchestration of network slicing in 2021 (ETSI GS ZSM 003 V1.1 June 2021). The issue of management exposure distinguishes two scenarios. In the first scenario, the vertical customers provide the communication service-related Service Level Agreement (SLA) requirements to operators. The slice information is invisible to vertical customers. These requirements specify SLA of requested communication services, together with other business-related information (e.g., communication service lifetime, communication service charging/accounting, etc.). In this situation, the operator, as a service provider, provides individual vertical customers (other operators) with information about their ongoing communication services, including SLA fulfilment and assurance. Information on underlying network slices is not made available to vertical customers. In the second case, which is essentially a Network Security as a Service (NSaaS) scenario, a dedicated network slice can be offered to a vertical. Unlike in the first scenario, the vertical customer is slicing-aware. The operator permits the vertical to use the provided network slice instance and, optionally, to manage it. Simplified, in the first scenario radio frequency holder as an access service provider is in control of all the information about the network slice and sends it upon request to another operator as a service provider, while in the second scenario, there is an agreement of offered slice, including all the information provided in advance, and management of the slice could be managed by not a licence holder but another operator of network access.

According to definition and use cases, AI-enabled network slicing is undoubtedly cross-domain, cross-service, and cross-user-oriented. ETSI defined some standards. For this reason, AI-enabled network slicing must meet the above-mentioned requirements to fully integrate and guarantee equal access. There are, as cited above, some common standards in this matter; therefore, the most applicable known standards that correspond to the desired functions should be used. Although with caution, as no special standardization for AI-enabled network slicing exists, the relation is made to a general standard.

To evaluate the new approach to obligatory spectrum sharing between intra- and inter-service sharing among spectrum holders, a comparison of AI techniques used in network slicing with the requirements of usage priority and coexistence rules, the avoidance of harmful interference, and the principles of a dynamic and efficient, up-to-date database with correlated standards is needed. The next part of the research focused on the above overview of the characteristics of the main AI techniques and DNA and ETSI requirements, and identifies potentially unmet or challenging regulatory requirements.

Inquiring Machine Learning, characterized by analyzing large datasets, identifying patterns, relationships, and insights that inform network slicing for key tasks such as classification, prediction, clustering, and pattern recognition, meets all the basic regulatory and standard requirements. For a dynamic database that is directly accessible, ML requires close cooperation among all users, as the AI system is populated with up-to-date data in real time. Large datasets must be processed; therefore, a common labeling standard is essential to ensure high-quality data. This is suitable only for NSaaS.

Deep Learning (DL) in network slicing is typically used to predict network congestion and to proactively allocate resources, such as bandwidth and computing power. It must be shown that it is also usable for intra- and interservice. DL is also used on large datasets and labeled data. The database for DL must be completed on time and contain high-quality data. A large dataset in this context requires extensive data labeling and a shared understanding among users of the data.

Reinforcement Learning (RL) in network slicing learns optimal programming parameters to improve Quality of Service (QoS) by maximizing the long-term cumulative reward. RL enables policies to adapt dynamically to network conditions, such as adaptive routing and the scaling of network slices. RL in network slicing could lack the ability for inter- and intraservice performance and usage priority. Despite the proven benefits, when a training dataset in RL is unavailable, the problem in the AI-enabled network slice is not a small state space, and using RL beyond adaptive routing, including scaling the network slices, is problematic. Such a database could not be accurate without the input of the desired parameters.

Deep Reinforcement Learning (DRL) builds on agents that interact with their environment in a closed-loop manner, an observation-action-reward mechanism. DRL algorithms enable continuous slice optimization, learning optimal policies for slice admission, scaling, and termination based on Service Level Agreement (SLA) parameters like latency and reliability. DRL seems to be more than capable of inter- and intraservice and usage priority and type of usage allowed. On the other hand, the issue may be the interpretability of results due to their closed-loop nature and the multi-agent environment, and a dynamic database like this may not be attainable.

Federated learning relies on agents located at edge nodes that collect local performance statistics and cooperatively train a common global model without sharing raw user data. FL depends strongly on local performance and devices, and it might ignore the big picture of the networks as a whole. To ensure unbiased and equitable access, the classification of devices from which the data are taken is the key. Explaining why local performance statistics from certain devices are used to inform decisions about network slices can be difficult. Therefore, uncertainty remains regarding how to access the discovered service; it can be provided and invoked directly.

Graph Neural Networks (GNNs) are perfect for capturing network topology and processing graph-structured data, for instance, of base stations. Although suitable for modelling network topology up to the core network, GNNs are not equally suitable for all intra-service and inter-service scenarios.

Large Language Models (LLMs) are already much integrated into Network Slicing Management and Orchestration (MANO) systems, in a multi-agent framework. LLMs translate even high-level user intent into concrete technical requirements to generate slice blueprints and manage the entire slice lifecycle in a human-readable, natural-language format. The use of human-in-the-loop is a logical consequence. For a dynamic database, time-critical decision-making is essential. When decisions are based on the translation of technical requirements, communication delays can occur; therefore, timely, dynamic decisions are not guaranteed.

Table 2: Assessment of AI Techniques Against Regulatory and Operational Requirements

AI Technique	Usage Priority	Coexistence Rules	Interference Protection	Dynamic Database	ETSI Service Functions	Explainability
ML	High	Medium	High	High	High	High
DL	High	Medium	High	High	High	Medium
RL	Medium	Medium	Medium	Low	Medium	Medium
DRL	High	High	High	Medium	High	Low
FL	Medium	Medium	Medium	Medium	Medium	Low
GNN	Medium	Medium	Medium	Medium	Medium	Medium
LLM	High	High	Medium	Low	High	Medium

(Source: Author's own work)

Table 2 summarizes the qualitative assessment of seven AI techniques against the regulatory and operational requirements relevant to AI-enabled network slicing. The results indicate that no single AI technique fully satisfies all regulatory, technical, and governance requirements. Instead, different techniques exhibit distinct strengths and limitations depending on the assessed criterion.

Machine Learning (ML) and Deep Learning (DL) demonstrate strong capabilities in spectrum usage prioritization, interference prediction, and operational automation. Their relatively mature deployment models and broad adoption in telecommunications environments support efficient implementation of ETSI ZSM service management functions. However, increasing model complexity may reduce transparency and explainability, particularly in deep learning-based decision processes.

Reinforcement Learning (RL) and Deep Reinforcement Learning (DRL) show significant potential for dynamic resource allocation and autonomous network optimization. In particular, DRL achieves high alignment with spectrum-sharing requirements because of its ability to continuously adapt to changing network conditions. Nevertheless, the decision-making processes of DRL models often remain difficult to interpret, creating challenges for regulatory transparency, accountability, and auditability.

Federated Learning (FL) offers advantages in distributed learning environments by reducing direct data sharing between participating entities. While this approach can contribute to privacy preservation and support decentralized management scenarios, its effectiveness depends on coordination mechanisms and may introduce additional operational complexity.

Graph Neural Networks (GNNs) provide valuable capabilities for modelling complex network relationships and dependencies. Their suitability is particularly evident in large-scale network slicing environments where resource allocation decisions depend on interconnected network elements. However, their practical application in regulatory spectrum-sharing scenarios remains comparatively less mature than other approaches.

Large Language Models (LLMs) achieve high scores in service orchestration, intent interpretation, and support for ETSI ZSM functions. Their ability to process human-readable policies and translate regulatory requirements into operational actions makes them particularly relevant for intent-based network management. However, LLMs are not inherently optimized for real-time spectrum allocation decisions and require robust governance mechanisms to mitigate risks related to accuracy, explainability, and accountability.

Overall, the assessment suggests that DRL and LLM-based approaches offer the strongest potential for supporting future AI-enabled network slicing. Nevertheless, their deployment in regulated spectrum-sharing environments will require complementary explainability mechanisms, human oversight, and alignment with emerging AI governance and telecommunications regulatory frameworks.

5 DISCUSSION

According to findings, AI-enabled network slicing can pave the way toward equal access to connectivity. DRL and LLM-based architectures appear the most promising candidates for advanced AI-enabled network slicing. However, both approaches still face significant challenges regarding explainability, auditability, and real-time database dependency, which must be addressed through specialised XAI mechanisms and regulatory safeguards. The assumption is that, in the future, a combination of AI techniques will be used to ensure equal access for competitive service providers and radio frequency holders. A shared database for spectrum usage is already planned by the EU legislator (DNA). This database is defined as dynamic and coordinated by Member States of the EU. Spectrum holders are treated as user seekers and obligated parties, rather than as data holders. The database should include geolocation information and data for monitoring radio spectrum usage opportunities, but DNA provides no additional details. The data for AI-enabled network slicing relies on patterns of radio frequency usage common to various wireless networks and spectrum holders. An administrative approach to defining the necessary data for network slicing, given the shared use of the radio frequency spectrum, is not appropriate. Spectrum holders, as communications providers, already report to national regulators all data necessary for monitoring development in tele-

communications. Those are historical data. DNA forces collecting data on holders of radio spectrum rights of use for the geolocalisation of existing radio spectrum uses, and nothing more. This limited in content database is not AI-ready. A dynamic database should rely on real-time data, and it is debatable if national authorities and not spectrum holders are capable of establishing and collecting real-time data for an AI-enabled network slice, as dynamics happen in different networks from various operators.

6 CONCLUSION

In conclusion, this study affirms the hypothesis that diverse AI algorithms—ranging from Machine Learning (ML) and Deep Learning (DL) to advanced techniques like Deep Reinforcement Learning (DRL), Federated Learning (FL), Graph Neural Networks (GNNs), and Large Language Models (LLMs)—demand tailored Explainable AI (XAI) strategies to mitigate equity and governance challenges in 6G network slicing. Key findings reveal strong alignment with core regulatory requirements under the proposed Digital Networks Act (DNA) and ETSI Zero-touch Service Management standards, including usage priority, coexistence rules, interference protection, and service invocation. However, persistent gaps emerge in real-time data quality, unbiased decision-making, timeliness, and explainability, particularly for complex models like DRL and LLMs, which risk discriminatory access barriers in dynamic, cross-domain environments. From a broader perspective, these results underscore a tension between AI's transformative potential for spectrum efficiency and its „black-box" opacity, which could exacerbate digital divides if unchecked, especially in heterogeneous 6G ecosystems supporting eMBB, URLLC, and mMTC.

For best practice, operators should prioritize shared frameworks that integrate DNA's mandatory intra- and inter-service sharing with ETSI's cross-domain integration, emphasizing dynamic geolocation databases to enable transparent resource allocation. Adopt algorithm-specific XAI tools—e.g. feature attribution for DL or policy visualization for RL, to enhance accountability, alongside standardized data labeling and privacy-preserving FL to ensure equitable access without compromising autonomy.

Unsolved issues include the lack of universal standards for AI-enabled slicing, potential biases in decentralized learning, and scalability in ultra-dense networks. Possible solutions involve hybrid XAI-regulatory models, such as certification schemes for AI agents and real-time auditing protocols. Further research could explore quantitative simulations of these frameworks in live 6G testbeds, investigate emerging AI paradigms such as quantum-enhanced learning, or conduct comparative analyses across global regulatory regimes to refine equitable governance and foster inclusive innovation in future wireless paradigms.

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