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Revisiting the Technological-Organizational-Environmental (TOE) Framework and Diffusion of Innovation (DOI): A Theoretical Review for Artificial Intelligence (AI) Adoption

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Abstract:

While the TOE framework emphasizes contextual domains such as technological readiness, organizational capabilities, and environmental pressures, the DOI theory focuses on innovation attributes and the diffusion process. The study advances a holistic framework that synthesizes these perspectives, linking why organizations adopt AI with how innovation diffuses across social and institutional systems. This study revisits and integrates these two foundational models to develop a cohesive theoretical lens for understanding AI adoption in underdeveloped economies. The study adopted a conceptual and theoretical review design and employed a structured literature review and thematic synthesis to identify patterns, overlaps, and gaps in TOE-DOI-based research. The study revealed that integrating DOI's innovation characteristics with TOE's contextual determinants enhances the explanatory power for AI adoption, particularly in a limited resources context. The integrated multi-theoretical lens addresses the constraints of each theory, embedding behavioural, structural, and institutional dimensions often overlooked in fragmented model studies. The study contributes to the theoretical discourse by proposing a multi-level context framework for AI adoption. Practically, it provides policymakers and managers with guidance aligning innovation perception with organizational readiness and external pressures.

Keywords:

TOE Framework, Diffusion of Innovation Theory, Emerging Economies, Artificial Intelligence

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Introduction

The Technological-Organizational-Environmental (TOE) Framework, introduced by Tornatzky et al. (1990), is a model that integrates multi-contextual domains – technological, organizational, and environmental – used to comprehend and explain why organizations adopt technological innovations. This framework emerged in the late 1980s as a response to the complexities of integrating technological innovations into business operations. During the rapid technological advancements in information systems and manufacturing, the organizations were grappling with the adoption of complex IT systems and computer-aided manufacturing systems, and the existing models, such as the Diffusion of innovation by Rogers and Williams (1983) and Technology Acceptance Models (TAM) by Davis (1993) which focused more on the compatibility and relative advantage, and overlooked success factors beyond just technological feasibility. Tornatzky et al. (1990) addressed this gap and suggested that the success of technological adoption by an organization is not only shaped by innovation attributes but also organizational capabilities and external pressures. Grounded in general systems theory by Von Bertalanffy (1968), the TOE framework conceptualizes organizations as open systems influenced by internal structures and external conditions, introducing three interconnected contexts – technological, organizational, and environmental – that collectively determine adoption outcomes.

The early empirical application of TOE centred on information technologies, specifically, the adoption of electronic data interchange by firms. Using the TOE, the study by Iacovou et al. (1995) reveals that external pressure and organizational readiness significantly influence the adoption of electronic data interchange (EDI) among small firms. These studies established TOE as a critical framework for IT investigating technological adoption, laying the foundation for its broader application across industries. TOE has evolved into a flexible framework applicable to complex technologies, providing a comprehensive perspective of how internal and external factors interact to shape organizational adoption behaviour.

Complementing the TOE perspective, the diffusion of Innovation (DOI) theory, introduced by Rogers and Williams (1983), is a fundamental framework underpinning how emerging technology innovations are spread within and across various organizations and societies. Grounded in the sociological and anthropological studies of the mid-20th century, the DOI framework emphasizes the process and characteristics that drive the spread of innovations across societies and organizations. Early studies by Ryan and Gross (1943) laid the foundation for Rogers and Williams (1983)'s work by the prominence of social and temporal dimensions of adoption. Rogers' subsequent work expanded this foundation by proposing five key innovation attributes – relative advantage, compatibility, complexity, trialability, and observability – that significantly influence the adoption rate.

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While originally used to study agricultural and health innovations, DOI evolved into a universal theory applicable to information systems and organizational technologies. Key studies such as Moore and Benbasat (1991) applied the DOI to explore the adoption of information systems, while Rogers and Shoemaker (1971) conducted diffusion research by adapting the DOI to examine planning innovation in developing countries. These studies emphasize attributes such as relative advantage and compatibility as critical, leading to DOI's integration with contextual models such as the TOE framework. This integration captures DOI's main limitation – its limited attention to organizational and environmental dimensions – by embedding technological attributes within broader contextual factors. The complementary relationship between the two theories allows the TOE Framework to provide insight into how technological, organizational, and environmental factors influence the adoption of AI (Oliveira & Martins, 2011; Tornatzky et al., 1990), while the DOI theory provides insight into how innovation attributes drive technology diffusion (Alqahtani & Orji, 2020; Rogers, 2003; Rogers & Williams, 1983).

Both frameworks remain central to contemporary technology adoption research, particularly in the era of artificial intelligence (AI), cloud computing, and other disruptive innovations. In emerging economies such as South Africa, where economic disparities, infrastructure limitations, and regulatory pressures are prevalent, the integration of these frameworks is critical. It captures the interplay between organizational capacity, environmental constraints, and perceived technological benefits in shaping adoption outcomes. Integrating TOE and DOI provides a holistic and context-sensitive framework that captures the gap between technological attributes and systematic dimensions, enabling a comprehensive understanding of the AI adoption process in a resource-constrained environment. By integrating the DOI's focus on innovation attributes with TOE's emphasis on contextual readiness, this study revisits both frameworks to develop a theoretically grounded agenda for AI adoption in emerging economies.

Research Objectives:

This study aims to achieve the following objectives:

- To review the evolution, applications, and critiques of the TOE framework and DOI theory in technology adoption research.
- To identify synergies and gaps between TOE and DOI for explaining AI adoption in emerging economies.
- To propose an integrated conceptual framework that synthesizes TOE's contextual domains with DOI's innovation attributes.
- To outline a research agenda for empirical validation and extension of the integrated model in resource-constrained settings.

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Literature Review

Expansions and Current Application to Disruptive Technologies

The evolution of both the TOE framework and DOI theory reflects how technology adoption research has adapted to different waves of innovation. Both frameworks have expanded to accommodate the proliferation of information and communication technologies (ICTs), enterprise systems, and disruptive innovations such as AI, Internet of Things (IoT), and blockchain.

In the 2000s, the TOE framework gained significant expansion. This increase was driven by the rapid increase of internet-based technologies and globalization. The flexibility of the TOE framework accommodates various industries and technologies, ranging from production to services. The rise of e-commerce, customer relationship management (CRM), and enterprise resource planning (ERP) software prompted researchers like Zhu et al. (2003) to apply TOE to a broader range of industries and innovation. Zhu et al. (2003) applied TOE to e-commerce in European firms and identified competitive pressures, organizational resources, and technological readiness as critical determinants of e-commerce adoption by these firms. Similarly, Pan and Jang (2008) followed the same approach and applied TOE to ERP in the Taiwan communication industry and identified managerial support and vendor partnership as key determinants of ERP adoption by the industry. These studies refined TOE by emphasizing constructs such as inter-organizational collaboration and top management, establishing it as a flexible analytical model across industries and technologies.

Building on this foundation, parallel developments in DOI integrated its attributes into organizational contexts, further supporting multi-theory approaches. DOI - originally developed to explain the diffusion of agricultural and health innovations (Ryan & Gross, 1943), was increasingly applied to organizational and technological contexts during the same period. This includes a study by Premkumar et al. (1994) who applied the DOI to study the adoption of electronic data interchange (EDI) while Bradford and Florin (2003) focused on ERP systems adoption. The organizational context of the TOE framework complements the DOI theory, leading to the integration of the two theories. Rogers provided insight from these applications and refined theory in the third and fourth editions of Diffusion of innovation to address organizational adoption. In refining the theory, Rogers introduced the concept of innovation-decision types. The DOI theory expansion includes researchers applying this theory to emerging markets. Studies include Agarwal and Prasad (1998), who conducted diffusion-based research to explore IT adoption in developing countries.

The 2000s and 2010s saw both frameworks evolve to capture disruptive technologies that fundamentally reshape industries. Studies like Seethamraju (2015) and ICAEW (2017) applying TOE to explore the adoption of cloud-based accounting systems and data analytics tools, respectively, provided a

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foundational research for AI adoption. Recent key studies, including Gangwar et al. (2015), Addy et al. (2024), and Cheung et al. (2023) have extended the application of TOE to related technologies. Competitive pressures, technological complexity, and organizational readiness are identified to be key factors when Gangwar et al. (2015) investigated the adoption of cloud computing. When investing in ERP adoption by SMEs in Nigeria, Cheung et al. (2023) emphasized the role of government support in a limited resource setting. Addy et al. (2024) applied TOE to investigate the adoption of building information modelling (BIM) and augmented reality (AR) in Ghana, and highlighted that external support, competitive pressures, trading partners' readiness, and organization size influence and inhibit the BIM-AR at the company level.

Similarly, DOI continued to evolve with these technological shifts. The flexibility of the DOI theory has made it a crux of technological research, especially in professional services (Seethamraju, 2015). For instance, Alsheibani et al. (2018) adopted the DOI to study AI adoption (i.e., organizational readiness) at a firm level, emphasizing attributes such as trialability and perceived benefit to drive the adoption. In South Africa, Maduku et al. (2016), used DOI to study technology adoption at an SME level, finding that compatibility and observability in a resource-constrained economy are important and critical. This progression reflects DOI's second paradigm shifts – from descriptive models focused on explaining diffusion patterns to predictive models that empirically test hypotheses and relationships (Moore & Benbasat, 1991; Oliveira & Martins, 2011).

Overall, both frameworks have undergone methodological and conceptual shifts. TOE has transformed into an integration with other theories, such as the Resource-Based View (RBV) and institutional theory, to improve its explanatory power (Oliveira & Martins, 2011; Zhu & Kraemer, 2005). DOI has shifted toward context-specific applications and a multi-theoretical lens to capture organizational and environmental complexity (Hossain & Quaddus, 2011; Lyytinen & Damsgaard, 2001). These developments have expanded the boundaries of technology adoption research and provided a foundation for understanding emerging technologies like AI.

Integration of the TOE and the DOI Framework

Although TOE and DOI emerged from different theoretical traditions, their integration provides a powerful, holistic framework for studying technological innovation in organizations. TOE focuses on the contextual determinants of adoption while DOI emphasizes the characteristics of innovations and the social processes influencing their diffusion. When integrated, the frameworks complement each other by linking why organizations adopt technologies with how those technologies diffuse across social systems (Oliveira & Martins, 2011).

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At the **technological level**, DOI's attributes – relative advantage, compatibility, complexity, trialability, and observability – enhance the technological context of TOE by detailing the perceptions that drive adoption decisions. For instance, Alsheibani et al. (2018) adopted the DOI to study AI adoption at a firm level, emphasizing attributes such as trialability and perceived benefit influence AI readiness, while Seethamraju (2015) emphasized compatibility and complexity in cloud computing-based ERP adoption. This combination captures tangible and cognitive drivers of innovation adoption.

At the **organizational level**, TOE's inclusion of managerial commitment, resource readiness, and organizational culture provides a context within which DOI's innovation attributes operate. In developing economies, internal capacity such as skills, financial resources, and leadership support determines the degree to which DOI's perceived advantages and translated into implementation. RBV aligns with this integration, emphasizing that organizational resources and capabilities enhance firms' ability to capitalize on innovative technologies.

At the **environmental level**, TOE's attention to external pressures and institutional forces complements DOI's recognition of social and communication influences. In emerging economies, where cultural norms, regulatory environments, and market competition are dynamic. Hossain and Quaddus (2011) demonstrated that regulatory uncertainty and infrastructural constraints shape technology adoption in Bangladesh, while Maduku et al. (2016) found similar environmental and cultural influences in South African SMEs. DOI's sensitivity to social and cultural diffusion processes helps to fill TOE's limited focus on human factors and behavioural dynamics.

Integrating TOE and DOI is particularly advantageous for studying AI adoption in emerging economies. AI represents a multifaceted innovation that combines technical sophistication with organizational transformation. The TOE framework explains how environmental readiness, institutional support, and resource constraints affect AI adoption, while DOI accounts for managerial perceptions of AI's relative advantage, complexity, and trialability. Combined, these frameworks provide a multi-theoretical lens that captures the structural, behavioural, and contextual dimensions of AI diffusion in resource-limited environments.

Critiques of the TOE Framework and DOI Theory

Since its introduction, the TOE framework has been admired for its flexibility and comprehensive approach to assessing and exploring organizational innovation adoption. The TOE framework has been widely adopted and applied by many researchers in various studies and contexts; however, the academic community has critiqued this framework and sparked debates within the research space. Similarly, despite its widespread use, the research community has criticized DOI theory, leading to debates that highlight its limitations. The debates and critiques are centred around the applicability of

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TOE regarding its methodological and contextual constraints. Key critiques and debates include a lack of specificity in construct, empirical rigor, general contextualization, static versus dynamic nature, and limited focus on human factors. Baker (2011) argue that TOE results in inconsistent findings across studies because the three domains of TOE enable considerable variability in variable selection. These inconsistent findings make it difficult to track and compare results for cumulative knowledge. Another significant critique is highlighted by Zhu et al. (2003) who suggest that TOE is inherently static, suggesting that it does not capture a dynamic iterative process, but captures a snapshot of adoption factors. The static nature of the TOE framework reduces its explanatory power as it does not capture how firms navigate the adoption challenges over time.

Gangwar et al. (2015) further argues that TOE's organizational and environmental contexts have a limited focus on human factors, which are critical for the adoption of technology. Human factors include employee resistance to change, perception of the user, and managerial cognition (Gangwar et al., 2015). Although studies like Zhu et al. (2003) and Low et al. (2011) show successful use of TOE in developed economies, Hossain and Quaddus (2011) question its applicability to less developed economies with constrained resources. TOE's methodological weaknesses have sparked debates in the research community and Baker (2011) amongst others, argues that TOE-based studies lack robust empirical rigor. These methodological weaknesses, including lack of triangulation, small sample sizes, and reliance on a single-method approach, undermine the framework's empirical rigor. Critiques of DOI mirror many of these concerns.

Addressing these critiques through integration provides a pathway for advancing technology adoption theory. Combining TOE and DOI offers complementary strengths – DOI provides perceptual and behavioural depth into TOE's structural model, while TOE contextualizes DOI's innovation attributes within broader organizational and environmental systems. This integrated approach also aligns with the need for a multi-theoretical lens with a staged or behavioural model. Fichman and Kemerer (1999) proposed a stage-based model to enhance temporal sensitivity, while Venkatesh et al. (2016) introduced the Unified Theory of Acceptance and Use of Technology (UTAUT) to incorporate human factors. Integrating these models enables a dynamic, process-oriented understanding of technology adoption that captures both the evolution of organizational readiness and user acceptance. In the context of AI adoption in emerging economies, this multi-theoretical integration is particularly critical. AI adoption unfolds in iterative phases, driven by evolving managerial perceptions, organizational learning, and regulatory adaptation. Integrating TOE and DOI (and other frameworks such as TAM or UTAUT) allows researchers to examine how contextual constraints, critical values, and perceived benefits interact over time. This integration moves beyond static models to develop contextually grounded, predictive frameworks that better reflect the realities of digital transformation in emerging economies.

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Conceptual Synthesis

Integrating these theories enhances the explanatory power, addresses the critiques of each theory's approaches, and provides a novel model specifically tailored to a developing economic context, characterized by cultural differences, regulatory pressures, and economic disparities. The framework intends to guide empirical research and provides practical implementation strategies for businesses intending to adopt AI. DOI contributes to the TOE framework by enriching its technological dimension with innovative attributes that shape managerial perceptions and intention to adopt. TOE then offers the structural foundation that situates these perceptions within organizational internal capabilities and environmental pressures. This alignment captures the micro-level behavioural insights of DOI with a macro-level systematic view of TOE, producing a cohesive framework that captures both perceptual and contextual dimensions of adoption. The synthesis addresses the limitations inherent in each theory. TOE's lack of human and behavioural depth is addressed by DOI's emphasis on social influence, communication networks, and user perceptions. On the other hand, DOI's static model gains explanatory power through TOE's dynamic inclusion of organizational readiness and environmental contingencies. This synthesis enables a more holistic explanation of AI adoption that encompasses technical feasibility, organizational readiness, and socio-cultural fit. The integrated framework thus advances technology adoption theory by combining cognitive, organizational, and institutional dimensions, critical in contexts where economic disparities, regulatory pressures, and diversity coexist.

Application to Emerging Economies

Existing studies on AI adoption research focus predominantly on developed markets such as the United States of America, Europe, where there are adequate resources or infrastructure, stable regulatory frameworks, and cultural dimensions that are significantly different from developing markets. This synthesis provides insights into AI adoption in emerging economies. DOI captures the perceived value, risks, and usability of AI, while TOE contextualizes these perceptions within the structural realities. This integration perspective explains the interplay between perception and uncertainty, emphasizing that successful AI adoption requires both favourable innovation attributes and an enabling organization-environmental ecosystem. In summary, the theoretical synthesis of DOI and TOE creates a multi-level, contextual model of AI adoption. It captures technological characteristics with systemic enablers and constraints, providing an adaptable framework for empirical testing across diverse economies. The integration provides a basis for developing a structured research agenda on AI diffusion in developing economies where contextual complexity and innovation potential intersect. As a result, DOI attributes affect perceptions that feed into TOE's contextual domains, TOE domains determine the organizational and environmental capacity to act on those perceptions, and both DOI and TOE predict the likelihood and trajectory of AI adoption and diffusion in developing markets.

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Methodology

The study adopted a conceptual and theoretical review design, employing a structured literature review and thematic synthesis to identify patterns, overlaps, and gaps in TOE-DOI-based research.

Research Design

The study followed a qualitative, explanatory theoretical review using a synthesis of literature (Oliveira & Martins, 2011). This approach reviews and interprets prior research works to advance theoretical understanding and identify future research directions. This approach is suitable for theory-building and agenda-setting in AI adoption research. A conceptual design is appropriate because the study seeks to develop a theoretical lens or propositions rather than measure variables. Both the DOI theory and TOE framework have been, to a greater degree, applied in empirical studies on technology adoption, providing a base for secondary evidence for synthesis. This methodological framework enables the identification of thematic connections, conceptual overlaps, and limitations for both frameworks.

Data Sources and Selection Criteria

The study relies on secondary data collected from peer-reviewed journals, conference proceedings, and institutional reports. To ensure a comprehensive and multidisciplinary coverage of literature, the sources were obtained from major academic databases that are widely used in research, including Google Scholar, Web of Science, Scopus, and ScienceDirect. Search boundaries were limited to English-language publications, focusing on peer-reviewed sources to capture the evolution from foundational TOE/DOI literature to contemporary AI applications. An initial search yielded approximately 150 articles; after abstract screening and full-text review, 45 studies were included based on relevance to TOE, DOI, or AI adoption in emerging economies.

The selection process: (1) The selected literature either applied or discussed the TOE, DOI, or both frameworks in the context of technology adoption; (2) Organizational or firm-level focus - The studies selected focus on the adoption of technologies at the organizational level, particularly in emerging economies; (3) Chronological evolution - To capture the historical evolution of DOI theory and the TOE framework, the studies incorporating this evolution were selected to reflect chronological evolution from early information systems to the contemporary AI and digital transformation context. The search employed a combination of these key terms: “TOE model”, “TOE framework”, “DOI theory”, “AI adoption”, “Emerging economies”, and “Developing countries”.

Analytical Procedures

To enable a competitive and integrative interpretation of literature, providing a theoretical foundation for conceptual synthesis, the study followed a qualitative content analysis and thematic synthesis approach.

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This procedure involved a systematic review, coding, and interpretation of literature to capture patterns and theoretical interconnectedness between TOE and DOI. The process included: (1) Descriptive mapping, cataloguing literature into chronological development, theoretical foundations, and empirical applications; (2) Grouping findings under TOE contexts – technological, organizational, and environmental – and DOI attributes – relative advantage, compatibility, trialability, and observability; (3) Integrative synthesis to identify overlaps and complementariness, developing a cohesive TOE-DOI framework for AI in emerging economies.

Validity, Rigor, and Ethical Considerations

Methodological rigor was ensured through a transparent approach aligned with systematic review guidelines (Oliveira & Martins, 2011). Strategies included a multi-database search to reduce bias, inclusion of only theoretically or empirically relevant studies, and emphasis on conceptual integration over descriptive summary. The study used publicly available secondary data, involving no human participants or primary data collection. All sources are cited to maintain academic integrity and uphold ethical standards of scholarship.

Conclusion and Future Research

The study revisited and integrated the TOE framework and DOI theory to provide a multi-theoretical lens for examining the adoption of AI in underdeveloped economies. The review demonstrated that, although each theory provides valuable insights independently, their integration aids in enhancing the explanatory power of each theory by linking innovation attributes with contextual domains of adoption. The TOE framework provides insights into technology adoption by providing a macro-level structure, integrating three contexts - technological, organizational, and environmental, critical to account for broad drivers for AI adoption. However, it underplays the importance of human and behavioural factors that influence decision-making. In contrast, DOI provides insights into technological adoption stages and innovation attributes at a micro-level structure, emphasizing attributes like relative advantage, compatibility, complexity, trialability, and observation. However, this theory is limited in capturing institutional and resource constraints contexts. This synthesis bridges these gaps, proposing a multi-level model that connects perceptions of innovation with structural enablers. Building on this synthesis, future research can extend and empirically validate the integrated multi-level model through country-specific variables. The TOE-DOI framework could incorporate behavioural models like TAM or UTAUT to explore user perceptions and resistance. Comparative studies across industries could uncover sector-specific factors, enhancing the model's contextual richness.

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