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Keywords

innovation adoption, TAM, TPB, DOI, UTAUT, sustainability, digital transformation, electric mobility.

I. Introduction

The swift advancement of digital technology and the worldwide need for sustainability have transformed how organisations and communities see innovation. Digital transformation has emerged as a pivotal factor in organisational competitiveness, whilst sustainable practices are widely regarded as vital for enduring development and resilience. As industries transition to low-carbon

economies and digital ecosystems, the adoption of innovations has become essential for future optimisation.

Research on innovation adoption has garnered considerable attention across several disciplines, including information systems, marketing, and environmental management. A significant problem is elucidating the reasons for individuals, organisations, and societies adopting or resisting new technologies, particularly when such advances require behavioural, cultural, and organisational transformations. In recent decades, numerous theoretical models have been formulated to elucidate the factors influencing adoption, with the Technology Acceptance Model (TAM) [1], the Theory of Planned Behaviour (TPB) [2], the Diffusion of Innovations theory (DOI) [3], and the Unified Theory of Acceptance and Use of Technology (UTAUT) [4] being the most prevalently utilised.

These models have undergone rigorous testing across domains such as information systems, e-commerce, mobile apps, and, more recently, in sustainable breakthroughs such as electric mobility, renewable energy technologies, and digital platforms for green logistics [5]–[7]. Nevertheless, the evidence is fragmented: each model emphasises distinct explanatory aspects, exhibiting differing levels of predictive efficacy across situations. The Technology Acceptance Model (TAM) highlights perceived utility and ease of use, whereas the Theory of Planned Behaviour (TPB) focuses on attitudes, subjective norms, and perceived behavioural control. DOI emphasises the attributes of innovations and their dissemination within social systems, whereas UTAUT consolidates several predictors into performance expectancy, effort expectancy, social impact, and enabling factors.

Comprehending the synergies and constraints of these frameworks is crucial for academics and professionals seeking to enhance innovation management in a sustainable context. This article rigorously compares the models, emphasising their strengths, shortcomings, and relevance in digital and sustainability-oriented situations. The contribution is twofold: first, to offer a literature-based view on the explanatory power of adoption models; second, to delineate integrative insights for management innovation strategies matched with sustainability objectives.

II. Literature review

A. Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), initially proposed by Davis in 1986 and subsequently formalised by Davis, Bagozzi, and Warshaw in 1989, is a prominent paradigm for forecasting technology uptake. The fundamental premise is that two primary factors—Perceived Usefulness (PU) and Perceived Ease of Use (PEOU)—shape consumers' perceptions towards a technology, therefore affecting their behavioural intention and actual utilisation.

Over time, the Technology Acceptance Model (TAM) has been expanded and enhanced, resulting in TAM2 and TAM3, which include social impact and enabling factors [3]. Additionally, scholars have integrated the Technology Acceptance Model (TAM) with supplementary frameworks, such as the Theory of Planned Behaviour (TPB) and the Unified Theory of Acceptance and Use of Technology (UTAUT), to enhance its explanatory capacity across many settings [4].

Recent research has utilised the Technology Acceptance Model (TAM) in the contexts of digitalisation and sustainability initiatives. Ajina (2024) amalgamated the Technology Acceptance Model with the Innovation Resistance Theory to elucidate green IT adoption, highlighting the interplay between environmental concerns and perceived utility [5]. Anser et al. (2020) introduced the Energy-Augmented Technology Acceptance Model (EA-TAM), emphasising the significance of energy efficiency perceptions in green logistics and corporate sustainability [6]. Schorr (2023) conducted a thorough assessment of the Technology Acceptance Model (TAM) applications in digital transformation research, affirming its significance as a resilient and flexible framework [7].

In sustainability contexts, the Technology Acceptance Model (TAM) has been particularly successful in examining the uptake of electric vehicles, renewable energy systems, and digital platforms for sustainable consumption. Nonetheless, a primary critique is its narrow emphasis on external variables, including cultural values, moral imperatives, and institutional influences, which are increasingly pertinent to the European Green Deal and national sustainability strategies [8].

Notwithstanding its constraints, the Technology Acceptance Model (TAM) remains fundamental for understanding the adoption of new technologies by individuals and organisations. Its simplicity, predictive capability, and flexibility render it a significant model, particularly when combined with comprehensive frameworks that consider social, environmental, and policy aspects.

B. Theory of Planned Behavior (TPB)

The Theory of Planned Behaviour (TPB), formulated by Ajzen (1991), enhances the preceding Theory of Reasoned Action (TRA) by integrating the concept of Perceived Behavioural Control (PBC) [9]. The Theory of Planned Behaviour posits that three principal elements influence behavioural intentions: Attitude towards the behaviour, Subjective Norms, and Perceived Behavioural Control. Collectively, these structures elucidate the rationale behind people's formation of intentions to act and the subsequent translation of these intentions into real behaviour.

The Theory of Planned Behaviour (TPB) has been extensively utilised in psychology, marketing, environmental management, and sustainability research. Its efficacy resides in its ability to encompass both logical assessments and the impact of social norms and perceived control, rendering it particularly appropriate for

circumstances where cultural and institutional elements are significant [10]. For example, in the realm of sustainable consumption research, the Theory of Planned Behaviour (TPB) has been used to predict intentions to recycle, adopt renewable energy solutions, or purchase eco-friendly products [11].

Recent modifications of the Theory of Planned Behaviour underscore the significance of including moral identity, corporate culture, and environmental consciousness into the paradigm. Zhai (2025) introduced an Extended Theory of Planned Behaviour (ETPB) by integrating moral identity and corporate green culture, therefore enhancing the model's prediction capability for pro-environmental behaviour among megaproject contractors [12]. Rizaldy (2025) similarly combined the Theory of Planned Behaviour (TPB) with the Diffusion of Innovations (DOI), demonstrating that the features of innovation interact with social and control variables to elucidate the uptake of green technologies [13].

Furthermore, the Theory of Planned Behaviour (TPB) has demonstrated efficacy when integrated with the Technology Acceptance Model (TAM) in examining technology uptake within sustainability-oriented frameworks. Dong et al. (2022) utilised an integration of the Technology Acceptance Model (TAM) and the Theory of Planned Behaviour (TPB) to examine the adoption of agro-ecological technology by Chinese farmers, revealing that perceived utility (from TAM) and subjective norms (from TPB) collaboratively influence behavioural intentions [14].

Despite its extensive application, the Theory of Planned Behaviour (TPB) has faced criticism for its excessive dependence on intention as a mediator, inadequately resolving the disparity between intention and actual behaviour. This constraint is especially pertinent in sustainability, where individuals may have pro-environmental goals yet fail to act in accordance owing to structural or economic impediments. Bridging this gap necessitates augmenting the Theory of Planned Behaviour with models that include situational and institutional variables.

C. Diffusion of Innovations (DOI)

The Diffusion of Innovations hypothesis (DOI), proposed by Rogers (1962; 2003), is a seminal and very important paradigm for elucidating the temporal dissemination of innovations within a social system. The pace of adoption is influenced by five principal properties of innovation: Relative Advantage, Compatibility, Complexity, Trialability, and Observability, as per DOI. Furthermore, DOI classifies adopters into categories—innovators, early adopters, early majority, late majority, and laggards—according to their readiness to accept novel concepts [16].

The efficacy of DOI resides in its capacity to encompass both individual-level perceptions and system-level diffusion processes, rendering it a prevalent model in technology management, healthcare, and environmental research [17]. For example,

it has been utilised to examine the uptake of renewable energy, eco-innovations, and digital platforms for sustainability [18].

In recent years, experts have underscored the necessity to revise DOI by integrating behavioural realism and systemic viewpoints. Galster (2025) advocated incorporating behavioural realism into diffusion models, emphasising that cultural and policy contexts substantially affect adoption trajectories [19]. Takahashi (2024) re-examined innovation diffusion processes, demonstrating that digital ecosystems transform the way inventions achieve critical mass within society [20].

Karakaya and Sarkar (2014) examined the transmission of eco-innovation and identified obstacles like substantial initial costs, regulatory ambiguity, and consumer scepticism, which frequently impede the extensive use of sustainable technology [21]. Khan et al. (2022) have utilised DOI in healthcare to examine the uptake of green innovation in hospitals, highlighting the significance of organisational preparation and leadership support [22].

Although the DOI framework is fundamental, it has faced criticism for neglecting the significance of social impact, institutional issues, and psychological elements, which are more clearly considered in models like TPB or UTAUT. Nonetheless, DOI persists in offering significant insights into the dynamics of sustainability transitions, particularly when integrated with behavioural or acceptance models.

D. Unified Theory of Acceptance and Use of Technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT), proposed by Venkatesh et al. (2003), serves as a comprehensive framework that integrates components from eight preceding theories, such as TAM, TPB, DOI, and the Innovation Diffusion Theory [23]. UTAUT delineates four primary factors of intention and usage: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions. The model also incorporates moderators such as gender, age, experience, and voluntary usage.

The UTAUT2 paradigm was subsequently expanded to include Hedonic Motivation, Price Value, and Habit, hence broadening its relevance to consumer scenarios outside organisational environments [24]. The growth of UTAUT has rendered it one of the most extensively utilised models in information systems and technology adoption research, especially concerning digital transformation and consumer-oriented technologies [25]. Recent studies have shown the effectiveness of UTAUT in the adoption of sustainability and green innovation. Selvi and Önem (2025) utilised UTAUT2 to examine the intention to adopt completely electric vehicles, demonstrating that performance expectancy and price value strongly impacted adoption choices [26]. Champahom et al. (2025) linked UTAUT2 with governmental policy aspects to analyse electric vehicle adoption across various vehicle types, affirming that conducive conditions and societal impact are essential

in mobility transitions [27]. Limpasirisuwan (2025) enhanced the model by including environmental awareness, hence augmenting its predictive capacity for battery electric vehicle (BEV) adoption [28].

Studies based on UTAUT in developing economies have highlighted the significance of institutional support and governmental incentives. Pratiwi (2024) integrated UTAUT2 with trust and policy satisfaction characteristics to elucidate EV uptake in Indonesia, emphasising the significance of contextual adaptability in sustainability-focused applications [29].

Despite its explanatory efficacy, UTAUT has faced criticism for its complexity and the necessity for significant contextual adaptation, which may restrict its parsimony in comparison to more straightforward models such as TAM. Its integrative character renders it especially effective for examining adoption in intricate situations where digital change, social impact, and sustainability objectives converge.

As shown in Table 1, each model offers unique explanatory variables that complement one another in sustainability-driven adoption studies.

Table 1. Comparative summary of adoption models

Model	Key Insights for Digital & Sustainable Innovation
TAM (Technology Acceptance Model)	Emphasizes perceived usefulness and ease of use. Strong predictors in digital contexts (e.g., fleet management systems, green IT), but limited in capturing social and normative drivers.
TPB (Theory of Planned Behavior)	Focuses on attitudes, subjective norms, and perceived behavioral control. Valuable for explaining sustainability behaviors (e.g., recycling, EV adoption), but faces the intention–behavior gap.
DOI (Diffusion of Innovations)	Explains diffusion dynamics via relative advantage, compatibility, complexity, trialability, and observability. Effective at the system-level (e.g., large-scale EV or eco-innovation adoption), less precise at individual level.
UTAUT / UTAUT2	Integrates technological, social, and contextual factors (e.g., performance expectancy, social influence, facilitating conditions). High explanatory power for EV adoption and green tech, though more complex to apply.

III. Comparative analysis and synthesis

The four examined adoption models—TAM, TPB, DOI, and UTAUT—offer complementary insights on innovation uptake. Each model has been verified across several domains; nevertheless, their explanatory efficacy differs based on the context and nature of the invention.

TAM provides a concise and highly predictive approach, focusing on judgements of utility and user-friendliness from a technology standpoint. This renders it especially appropriate for examining user interactions with digital platforms or onboard technology in electric vehicles, such as telematics, route optimisation systems, or fleet management software [30]. Nevertheless, the Technology Acceptance Model (TAM) alone fails to comprehensively account for the influence of regulatory incentives or organisational pressures that frequently dictate widespread adoption in freight mobility.

The Theory of Planned Behaviour enhances the analysis by incorporating social and normative aspects. Logistics operators in electric truck mobility frequently evaluate economic efficiency with reputational considerations and adherence to stakeholder expectations [31]. Subjective norms, such as client demand to decarbonise supply chains, and perceived behavioural control, including infrastructure availability and charging networks, directly influence adoption intentions. Nonetheless, the Theory of Planned Behaviour (TPB) encounters difficulties in bridging the intention–behavior gap, as individuals may articulate a readiness to adopt but ultimately refrain from action due to substantial investment costs or regulatory ambiguities.

DOI provides a system-level viewpoint, emphasising the attributes of innovation and classifications of adopters. In freight transportation, early adopters of electric vehicles are often major logistics companies or multinational corporations with environmental pledges, whereas smaller operators tend to be more cautious. The DOI elucidates how trialability and observability, shown by pilot projects demonstrating the efficacy of electric vehicles in urban distribution, may expedite broader dissemination. Nevertheless, DOI is less efficacious in forecasting individual decision-making within organisations, particularly where adoption necessitates intricate cost–benefit evaluations.

UTAUT and UTAUT2 amalgamate several constructs, rendering them exceptionally effective for elucidating adoption within intricate ecosystems such as urban freight electrification. Research indicates that performance expectancy (e.g., reduced long-term operating expenses), effort expectancy (e.g., seamless integration with digital fleet systems), and supportive conditions (e.g., governmental subsidies, charging infrastructure) are essential drivers [33]. Social influence significantly impacts firms as they strive to conform to competition and regulatory standards. Nonetheless, the model's complexity may pose difficulties for empirical validation

across various logistics marketplaces. Collectively, these frameworks indicate that no one model can comprehensively encapsulate the adoption processes of sustainability-driven breakthroughs like electric truck mobility. TAM is optimal for assessing technical usability, TPB emphasises behavioural and normative influences, DOI elucidates systemic dissemination, and UTAUT offers a comprehensive integration of technological, social, and environmental elements. An integrated approach that amalgamates various views provides the most thorough comprehension of the adoption of digital and sustainable technologies for both researchers and practitioners.

IV. Discussion: towards an integrated approach

The comparison research indicates that no singular adoption model adequately encompasses the intricacies of digital and sustainability-focused technologies. TAM elucidates technology perceptions, TPB highlights behavioural and normative implications, DOI addresses systemic spread, and UTAUT synthesises several determinants. Collectively, these viewpoints emphasise the necessity for a cohesive strategy in the adoption of innovation.

In the realm of sustainability transitions, especially concerning transportation and logistics, such integration is essential. The adoption of electric trucks for urban freight transport cannot be entirely attributed to perceived utility, as suggested by the Technology Acceptance Model, or to innovative features, as emphasised by the Diffusion of Innovations theory. Adoption is contingent upon a confluence of technological perceptions (e.g., cost efficiency, user-friendliness), behavioural factors (e.g., attitudes towards sustainability, normative pressures from clients and regulators), systemic characteristics (e.g., infrastructure preparedness, visibility of successful pilot initiatives), and contextual facilitators (e.g., policy incentives, conducive conditions).

This indicates that hybrid models—like TAM-TPB or UTAUT extensions incorporating sustainability constructs—provide enhanced explanatory capacity for both research and practice [34]. Recent research on the proliferation of electric vehicles and renewable energy has demonstrated that including environmental considerations, policy understanding, and organisational preparedness into adoption frameworks is successful [35].

From a management perspective, this comprehensive viewpoint allows decision-makers to formulate adoption strategies that extend beyond technology design and usability. Logistics firms contemplating the deployment of electric trucks must assess fleet management efficiency, regulatory compliance, market reputation, and long-term sustainability objectives. Governments and policymakers may utilise this by customising subsidies, infrastructure investments, and communication initiatives to target both rational and normative factors influencing adoption. The

integration of TAM, TPB, DOI, and UTAUT facilitates a multi-tiered research program.

- Micro-level: comprehending the individual decision-making processes of managers and drivers.
- Meso-level: examining organisational strategy and supply chain dynamics.
- Macro-level: examining diffusion trajectories influenced by legislation, incentives, and cultural values.

An integrated model for innovation uptake in sustainable transportation and digital transformation must extend beyond conventional predictors to include behavioural realism, institutional forces, and sustainability imperatives.

V. Conclusions

This research presents a comparative literature-based analysis of four predominant innovation adoption models—TAM, TPB, DOI, and UTAUT—within the framework of digital transformation and sustainability. The research indicated that although each model offers useful insights, none alone can adequately elucidate adoption processes in intricate fields such as electric transportation, green logistics, or renewable energy technology.

The Technology Acceptance Model (TAM) is crucial for understanding technology-specific perceptions of utility and user-friendliness, while the Theory of Planned Behaviour (TPB) addresses social and normative influences that are vital for sustainable transitions. DOI highlights diffusion dynamics and adopter classifications at the systemic level, whereas UTAUT amalgamates several variables into a comprehensive explanatory framework, particularly relevant for consumer and organisational settings.

The synthesis indicates that integrative approaches—merging technological, behavioural, systemic, and contextual perspectives—hold the most promise for enhancing both theory and practice. The use of electric trucks in urban freight transportation necessitates user acceptance of digital fleet technologies, normative alignment, infrastructural preparedness, and conducive policy frameworks.

This study underscores the need to enhance existing models by including characteristics associated with environmental concern, institutional trust, and sustainability imperatives. From a management standpoint, it emphasises the necessity of formulating adoption strategies that concurrently tackle technology usability, social legitimacy, and systemic feasibility.

Ultimately, enhancing the future of digital and sustainable innovation management requires transcending fragmented theoretical perspectives in favour of comprehensive frameworks that integrate innovation adoption with overarching social and environmental objectives. The article advances this objective by

providing a systematic comparative synthesis and delineating avenues for integrated adoption research.

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