

Formulating the Strategic Drone Integration Framework (SDIF) for Autonomous Drone Deployment in the UAE Oil and Gas Sector: A Conceptual Paper

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Abstract

Autonomous drone technology is increasingly used in the oil and gas sector for inspection, monitoring, methane detection, emergency response, and environmental surveillance. However, many drone initiatives remain limited to pilot projects or isolated operational applications because drone-generated data are not fully integrated into enterprise systems, operational workflows, and strategic decision-making processes. This creates an integration chasm between drone adoption and digital transformation value. This conceptual paper formulates the Strategic Drone Integration Framework (SDIF) for autonomous drone deployment in the UAE oil and gas sector. The framework proposes that Technical Integration Factors, Organizational Enablers, and External Enablers contribute to Drone Integration Maturity, which subsequently enhances Digital Transformation Performance. The paper also discusses the applicability of the SDIF in strategic planning, technical integration, organizational readiness, regulatory alignment, and sustainability performance. The proposed framework contributes to the literature by offering a conceptual model that explains how autonomous drones can move from isolated technological adoption to strategic integration. Future research should empirically validate the SDIF using quantitative methods such as

PLS-SEM.

Keywords: autonomous drones, Strategic Drone Integration Framework, oil and gas, UAE, drone integration maturity, digital transformation

1. Introduction

The oil and gas sector is undergoing rapid digital transformation driven by the need to improve operational efficiency, enhance safety, reduce costs, and meet environmental sustainability targets. Technologies such as artificial intelligence, digital twins, and advanced data analytics are increasingly being adopted to optimize operations and support data-driven decision-making (Mitacc Meza et al., 2024). In this context, **autonomous drone technology** has emerged as a critical enabler for inspection, monitoring, methane detection, and environmental surveillance.

In the United Arab Emirates (UAE), the adoption of advanced technologies is closely aligned with national strategies such as the **Net Zero 2050 initiative**, which emphasizes sustainability, emissions reduction, and digital innovation (United Arab Emirates Government, n.d.). Organizations such as ADNOC are actively investing in artificial intelligence and digital solutions to transform energy operations and enhance performance (Abu Dhabi National Oil Company [ADNOC] & Microsoft, 2025). Autonomous drones are increasingly being deployed in these efforts due to their ability to operate in hazardous environments, improve inspection efficiency, and generate high-quality operational data.

Despite these advancements, many drone initiatives remain limited to pilot projects or isolated operational use. The core issue lies not in the technology itself, but in the **lack of integration** between drone systems, enterprise digital infrastructure, and organizational processes. This creates an **integration chasm**, where drones produce valuable data but fail to deliver measurable strategic value.

Existing literature highlights drone capabilities and operational benefits but provides limited conceptual guidance on how drones can be integrated into broader digital transformation systems (Aromoye et al., 2025). Therefore, this paper formulates the **Strategic Drone Integration Framework (SDIF)** to address this gap and proposes a structured conceptual model linking integration enablers, maturity, and performance outcomes in the UAE oil and gas sector.

2. Literature Review

2.1 Digital Transformation in the Oil and Gas Sector

The oil and gas sector is increasingly moving toward digital transformation as companies seek to respond to operational, economic, safety, and environmental pressures. At the broadest level, digital transformation refers to the integration of advanced digital technologies into organizational processes, assets, and decision-making systems. In oil and gas operations, this transformation is visible through the use of artificial intelligence, digital twins, advanced analytics, automation, cloud platforms, and real-time monitoring systems. These technologies help organizations improve asset visibility, optimize maintenance, reduce operational risks, and support more informed decision-making.

Among these technologies, digital twins have become particularly important because they allow physical assets to be represented, monitored, and analyzed in digital environments.

Through digital twins, oil and gas companies can support predictive maintenance, real-time asset monitoring, and operational optimization. This shows that digital transformation is not only about adopting new technologies, but also about integrating data into operational and strategic decision-making processes (Mitacc Meza et al., 2024).

Within the UAE, digital transformation has become a strategic national and industrial priority. The country's focus on energy efficiency, emissions reduction, sustainability, and technological innovation has created strong pressure for oil and gas organizations to modernize their operations. National initiatives such as the UAE Net Zero 2050 Strategy further emphasize the importance of using advanced technologies to support environmental and operational goals (United Arab Emirates Government, n.d.). At the industry level, companies such as ADNOC are increasingly using artificial intelligence and digital platforms to enhance operational performance and sustainability outcomes (ADNOC & Microsoft, 2025).

2.2 Autonomous Drone Deployment in Oil and Gas

Within this wider digital transformation context, autonomous drones have emerged as a practical technology for improving oil and gas operations. Drones are particularly valuable because many oil and gas assets are located in hazardous, remote, offshore, or difficult-to-access environments. Traditional inspection methods often require human workers to enter risky areas, use scaffolding, or conduct time-consuming manual inspections. Autonomous drones can reduce these risks by enabling remote inspection, monitoring, and data collection.

Autonomous drones are now used for pipeline monitoring, offshore platform inspection, storage tank inspection, flare stack inspection, methane leak detection, emergency response, and environmental surveillance. These applications show that drones can improve inspection speed, increase data accuracy, reduce human exposure to danger, and support more frequent monitoring of critical assets (Aromoye et al., 2025).

Recent research also highlights the growing role of drones in environmental monitoring, particularly methane detection. Drone-mounted sensing systems can detect and localize methane emissions, making them useful for supporting emissions monitoring and environmental compliance (MacGruer et al., 2025; Soskind et al., 2023). This is especially relevant for the UAE oil and gas sector, where sustainability and emissions reduction are increasingly linked to national and corporate strategy.

2.3 Drone Data Integration and Value Creation

Although drones provide important operational benefits, their strategic value does not come from drone hardware alone. The real value of autonomous drones lies in the data they generate and how that data is transformed into actionable insight. Drone-generated data may include high-resolution images, thermal readings, LiDAR point clouds, geospatial information, and methane detection outputs, which are increasingly used for inspection, pipeline monitoring, and emissions detection in oil and gas operations (Aromoye et al., 2025; Bretschneider et al., 2024; MacGruer et al., 2025). These data must move through a value

chain that includes acquisition, processing, analysis, and integration into enterprise systems.

At this stage, the discussion moves from drone deployment to drone integration. For drone data to support digital transformation, it must be connected to systems such as digital twins, asset integrity platforms, maintenance management systems, data lakes, analytics platforms, and operational dashboards. Digital twin systems, for example, depend on continuous and reliable data inputs to support asset monitoring, predictive maintenance, and operational optimization (Mitacc Meza et al., 2024). Drone data can strengthen these systems, but only when it is properly processed, standardized, and integrated.

However, many organizations still use drones mainly as data collection tools. In such cases, drone outputs remain fragmented, stored separately, or used only for isolated inspection reports. This limits their strategic value because the data are not fully embedded into enterprise platforms or decision-making workflows. Without such integration, drone deployment may improve local inspection activities but fail to contribute to wider digital transformation performance (Mitacc Meza et al., 2024).

2.4 Technical, Organizational, and External Enablers

Because drone value depends on integration, several enabling factors are required. At the technical level, successful integration depends on system interoperability, data standards, cybersecurity, data pipeline robustness, and compatibility between operational technology and information technology systems. These technical factors determine whether drone-generated data can move securely and effectively from field operations into enterprise systems and digital platforms (Mitacc Meza et al., 2024).

However, technical capability alone is not sufficient. Organizational enablers are also needed to support scalable drone deployment. Leadership support, governance structures, workforce capability, digital culture, and change readiness influence whether drone initiatives remain isolated pilots or become enterprise-wide capabilities. Without clear governance and organizational commitment, drone projects may be implemented successfully at a local level but fail to scale across departments or assets.

External enablers also shape drone integration. These include regulation, vendor ecosystem maturity, industry standards, and policy alignment. In the UAE, drone operations are influenced by aviation rules and regulatory requirements that affect deployment, permissions, safety, and scalability. Therefore, regulatory alignment is a key condition for the successful use of autonomous drones in oil and gas operations (General Civil Aviation Authority [GCAA], 2025).

2.5 Research Gap

The reviewed literature shows a clear progression. Digital transformation is reshaping oil and gas operations, autonomous drones are becoming useful tools within this transformation, and drone-generated data can support strategic value when integrated into wider digital systems (ADNOC & Microsoft, 2025; Mitacc Meza et al., 2024). However, the literature also reveals an important gap.

Most existing studies emphasize the technical capabilities and operational benefits of drones, such as inspection efficiency, safety improvement, pipeline monitoring, and methane detection (Aromoye et al., 2025; Bretschneider et al., 2024; MacGruer et al., 2025; Soskind et al., 2023). Less attention has been given to how drone deployment becomes maturely integrated into organizational systems, workflows, governance mechanisms, and digital transformation performance measures. In particular, there is limited conceptual explanation of how technical, organizational, and external enablers jointly influence drone integration maturity, and how this maturity contributes to digital transformation performance.

This gap is significant in the UAE oil and gas context, where autonomous drone deployment must align not only with operational efficiency, but also with sustainability, regulation, national digital priorities, and enterprise-wide value creation (ADNOC & Microsoft, 2025; United Arab Emirates Government, n.d.). Therefore, there is a need for a conceptual framework that explains how autonomous drone deployment can move from isolated technological adoption to strategic integration. This need supports the development of the **Strategic Drone Integration Framework (SDIF)**.

3. Conceptual Framework Development

3.1 Overview of the Strategic Drone Integration Framework

Digital transformation in the oil and gas sector increasingly depends on the ability of organizations to integrate advanced technologies into operational systems, decision-making processes, and strategic performance goals. Within this transformation, autonomous drones have become important tools for inspection, monitoring, methane detection, emergency response, and environmental surveillance. However, the strategic value of drones is not achieved through deployment alone. Instead, value depends on how effectively drone technology and drone-generated data are integrated into wider digital ecosystems.

The SDIF is theoretically grounded in the Technology Organization Environment (TOE) framework, dynamic capability theory, and digital transformation maturity thinking. The TOE perspective explains how technological, organizational, and environmental conditions shape technology adoption and integration. Recent work extends this view by showing that TOE factors can be strengthened through dynamic capabilities, especially in contexts where firms must use technology to improve sustainability and competitiveness (Truong et al., 2026). Dynamic capability theory further supports the view that organizations must develop the ability to sense opportunities, seize technological value, and reconfigure resources in order to convert digital technologies into strategic advantage. In relation to digital transformation, this capability-based view is closely connected to digital maturity, where organizations gradually develop the capabilities needed to integrate technologies, processes, and people into a coherent transformation pathway (Leso et al., 2024). Maturity theory also explains how systems and organizational capabilities progress from initial and fragmented conditions toward more structured, repeatable, and optimized stages of development (Puik & Ceglarek, 2014).

Building on these theoretical foundations and the reviewed literature, this paper develops the

Strategic Drone Integration Framework (SDIF) as a conceptual model for explaining how autonomous drone deployment can create strategic value in the UAE oil and gas sector. The framework argues that drone adoption alone is insufficient to achieve digital transformation outcomes. Rather, value is created when drone systems, drone-generated data, organizational capabilities, regulatory conditions, and performance goals are strategically aligned.

The SDIF therefore shifts the focus from simple drone usage to drone integration maturity. In many oil and gas organizations, drones may already be used for inspection, monitoring, methane detection, and emergency response. However, these activities may remain limited if drone data are not connected to enterprise systems, operational workflows, asset integrity platforms, digital twins, or strategic performance indicators. The SDIF addresses this limitation by identifying the conditions required for mature, scalable, and value-driven drone integration.

Accordingly, the framework consists of five main constructs: Technical Integration Factors (TIF), Organizational Enablers (OE), External Enablers (EE), Drone Integration Maturity (DIM), and Digital Transformation Performance (DTP). Together, these constructs explain how technical readiness, organizational readiness, and external support contribute to drone integration maturity, and how this maturity subsequently enhances digital transformation performance.

3.2 The Conceptual Framework

The conceptual logic of the SDIF moves from broad integration conditions to specific maturity outcomes and, finally, to digital transformation performance. At the first level, the framework assumes that successful autonomous drone integration depends on the interaction of technical, organizational, and external enablers. This logic is consistent with the Technology Organization Environment framework, which explains that technology adoption is shaped by technological readiness, organizational capability, and environmental conditions (Tornatzky & Fleischer, 1990).

First, technical integration factors create the digital infrastructure required for drone-generated data to become useful. These factors include data capture, processing, standardization, cybersecurity, data pipeline robustness, and interoperability between operational technology and information technology systems. Such integration is necessary because drone data must be connected to enterprise systems, analytics platforms, digital twins, and decision-support tools before it can support operational and strategic decisions (Mitacc Meza et al., 2024; Aromoye et al., 2025).

Second, organizational enablers provide the internal conditions needed to scale drone deployment beyond isolated pilots. Leadership support, governance structures, workforce capability, digital culture, and change readiness help ensure that drone initiatives are aligned with business objectives and embedded into operational workflows. This reflects dynamic capability theory, which argues that organizations must sense technological opportunities, seize value from them, and reconfigure resources to achieve strategic advantage (Tece, Pisano, & Shuen, 1997; Teece, 2007).

Third, external enablers influence whether autonomous drone deployment can be implemented safely, legally, and sustainably. In the UAE oil and gas context, these include regulatory alignment, vendor ecosystem maturity, industry standards, aviation permissions, and national policy priorities. These external conditions are important because drone operations must comply with safety, airspace, and critical infrastructure requirements while also supporting national digital and sustainability agendas (General Civil Aviation Authority [GCAA], 2025; United Arab Emirates Government, n.d.).

These three groups of enablers are proposed to influence Drone Integration Maturity (DIM). Drone integration maturity refers to the extent to which autonomous drones and drone-generated data are embedded into organizational systems, operational workflows, digital platforms, and decision-making processes. From a maturity perspective, organizations progress from ad hoc and isolated drone use toward standardized, scalable, and optimized integration capabilities (Paulk et al., 1993; Westerman et al., 2014).

Finally, higher Drone Integration Maturity is expected to enhance Digital Transformation Performance (DTP). This performance may appear through improved inspection efficiency, reduced downtime, enhanced safety, lower costs, better environmental compliance, and stronger data-driven decision-making. Therefore, the SDIF suggests that autonomous drones create strategic value not through adoption alone, but through mature integration into the wider digital transformation ecosystem. Accordingly, the conceptual framework is developed as shown in Figure 1.

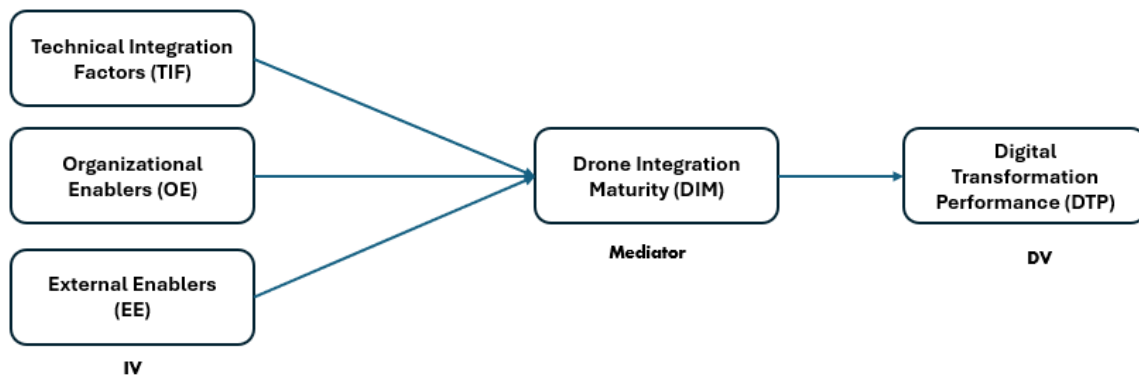


Figure 1. Conceptual framework of the Strategic Drone Integration Framework

The conceptual framework of the SDIF illustrates how autonomous drone deployment can move from technological adoption to strategic value creation. The framework proposes that **Technical Integration Factors (TIF)**, **Organizational Enablers (OE)**, and **External Enablers (EE)** create the conditions required for **Drone Integration Maturity (DIM)**. In turn, higher DIM enhances **Digital Transformation Performance (DTP)** in autonomous drone deployment. This relationship reflects the view that technology adoption produces

value only when it is supported by organizational capability, environmental alignment, and mature integration into business processes (Tornatzky & Fleischer, 1990; Teece, 2007; Westerman et al., 2014).

3.3 Development of Propositions

This study adopts a **conceptual approach**, and therefore the relationships within the Strategic Drone Integration Framework (SDIF) are presented as **propositions rather than hypotheses**. In academic research, hypotheses are typically used in empirical studies where relationships are statistically tested using quantitative data and analytical techniques such as PLS-SEM. In contrast, conceptual studies focus on theory building and framework development based on existing literature. As such, propositions are more appropriate because they express **theoretically grounded relationships that have not yet been empirically tested** (Whetten, 1989; MacInnis, 2011). These propositions provide a foundation for future empirical validation.

The constructs of the SDIF were systematically derived from the literature review by synthesizing key themes related to digital transformation, drone deployment, and technology integration in oil and gas operations. The literature consistently shows that the strategic value of autonomous drones does not arise from the technology itself, but from the extent to which drone-generated data are integrated into enterprise systems, operational workflows, and decision-making processes (Mitacc Meza et al., 2024; Aromoye et al., 2025). Based on this synthesis, five core constructs were identified: **Technical Integration Factors (TIF), Organizational Enablers (OE), External Enablers (EE), Drone Integration Maturity (DIM), and Digital Transformation Performance (DTP)**.

Technical Integration Factors (TIF) were derived from studies emphasizing the importance of system interoperability, data pipelines, cybersecurity, and integration with digital platforms such as digital twins and analytics systems. The literature highlights that drone-generated data must be processed, standardized, and securely transferred into enterprise environments to support operational and strategic use (Mitacc Meza et al., 2024). Without such integration, drone outputs remain fragmented and underutilized. Therefore, strong technical integration is expected to enhance the maturity of drone deployment.

Organizational Enablers (OE) were derived from digital transformation and technology adoption literature, which identifies leadership support, governance, workforce capability, and organizational culture as critical success factors (Westerman et al., 2014). The literature shows that many digital initiatives fail to scale due to weak organizational alignment and lack of internal capabilities. In the context of drone deployment, these factors determine whether drones remain isolated tools or become embedded in enterprise-wide operations. Thus, organizational enablers are expected to positively influence drone integration maturity.

External Enablers (EE) were derived from literature addressing regulatory frameworks, industry standards, vendor ecosystems, and policy environments. In the UAE oil and gas sector, drone deployment is strongly influenced by aviation regulations, safety requirements, and national digital strategies (GCAA, 2025; UAE Government, n.d.). These external

conditions shape the feasibility and scalability of drone operations. Therefore, supportive external environments are expected to facilitate higher levels of drone integration maturity.

Drone Integration Maturity (DIM) was derived from maturity model literature and from the identified research gap. Existing studies indicate that organizations often deploy drones at a pilot level without achieving full integration into digital ecosystems. Maturity models suggest that value is realized when technologies are embedded into processes, systems, and decision-making structures (Deloitte, 2020). Accordingly, DIM is conceptualized as the degree to which drones are integrated into operational workflows, digital platforms, and organizational processes, and is positioned as the central mediating construct in the framework.

Digital Transformation Performance (DTP) was derived from literature linking digital technologies to organizational outcomes such as operational efficiency, safety improvement, cost reduction, environmental compliance, and data-driven decision-making (Kaplan & Norton, 1996; Westerman et al., 2014). These outcomes represent the expected benefits of successful digital transformation. The literature suggests that such performance improvements are achieved when digital technologies are fully integrated into business processes, rather than used in isolation.

Based on this theoretical foundation, the following propositions are developed:

Table 1. The propositions

Proposition	Statement
P1	Technical Integration Factors enhance Drone Integration Maturity.
P2	Organizational Enablers enhance Drone Integration Maturity.
P3	External Enablers enhance Drone Integration Maturity.
P4	Drone Integration Maturity improves Digital Transformation Performance.
P5	Drone Integration Maturity acts as a mediating mechanism through which technical, organizational, and external enablers create digital transformation value.

These propositions reflect a **logical and theory-driven structure**, where technical, organizational, and external conditions enable integration, and integration maturity acts as the mechanism through which value is realized. This aligns with prior research emphasizing that digital transformation success depends on both technological and organizational capabilities rather than technology adoption alone (Westerman et al., 2014; Mitacc Meza et al., 2024).

Overall, the SDIF propositions are grounded in the literature and provide a structured basis for future empirical research. Subsequent studies may transform these propositions into testable hypotheses and validate the framework using quantitative methods such as PLS-SEM.

3.4 Capability Perspective of the SDIF

The SDIF can also be understood from a capability perspective. At a broad level, autonomous drone integration is not simply a technological activity, but an organizational capability that develops over time. This view is consistent with dynamic capability theory, which emphasizes the ability of firms to sense technological opportunities, seize value, and reconfigure resources to sustain strategic advantage (Teece, Pisano, & Shuen, 1997; Teece, 2007).

From this perspective, drone integration requires several interrelated capabilities, including governance and strategy, technology and data infrastructure, operational process integration, people and organizational readiness, value realization, and ecosystem engagement. These capabilities are important because oil and gas organizations operate in complex environments involving safety-critical assets, legacy systems, strict regulatory requirements, and cross-functional workflows.

Therefore, effective drone integration requires more than purchasing drones or conducting autonomous flights. It requires the coordination of technology, people, processes, data, regulation, and external stakeholders. Accordingly, the SDIF provides a structured way for UAE oil and gas organizations to assess readiness, identify integration gaps, and progress from isolated drone use toward scalable and strategically aligned deployment (Westerman et al., 2014; General Civil Aviation Authority [GCAA], 2025).

4. Applicability of the SDIF Framework

4.1 Strategic Application

The SDIF is applicable as a strategic roadmap for UAE oil and gas organizations seeking to move autonomous drone deployment beyond pilot projects. At the strategic level, the framework helps organizations align drone initiatives with broader business objectives such as operational efficiency, safety improvement, cost reduction, sustainability, and digital transformation. This is important because drone deployment should not be treated as a separate technological activity, but as part of a wider organizational transformation agenda.

Through the SDIF, managers can assess whether drone initiatives are linked to corporate strategy, asset management priorities, HSE objectives, and sustainability targets. This allows organizations to shift from experimental drone use toward enterprise-wide integration, where drones contribute directly to measurable strategic value.

4.2 Technical Application

At the technical level, the SDIF provides guidance on the infrastructure required to integrate drone-generated data into enterprise digital systems. This includes interoperability between drone platforms, OT systems, IT systems, data lakes, analytics platforms, and digital twins. Such integration is essential because drone data can only support decision-making when it is processed, standardized, secured, and connected to existing operational systems.

The framework therefore emphasizes data pipelines, cybersecurity, data quality, and system

compatibility. These elements are especially important for linking drone data with digital twins and analytics systems, which require reliable and continuous data inputs to support asset monitoring, predictive maintenance, and operational optimization (Mitacc Meza et al., 2024).

4.3 Organizational Application

The SDIF is also applicable as a tool for assessing organizational readiness. Even when technical infrastructure is available, drone initiatives may fail to scale if organizations lack leadership support, clear governance, skilled personnel, and change readiness. Therefore, the framework highlights the importance of organizational enablers in transforming drones from isolated operational tools into enterprise-level digital capabilities.

In practice, this means that UAE oil and gas organizations need clear roles, training programs, cross-functional collaboration, standard operating procedures, and executive sponsorship. These conditions help ensure that drone deployment becomes embedded in daily operations and long-term digital transformation planning.

4.4 Regulatory and Ecosystem Application

In the UAE context, the applicability of the SDIF also depends on regulatory and ecosystem alignment. Drone operations in oil and gas environments are affected by aviation regulations, airspace permissions, safety requirements, and restrictions related to critical infrastructure. Compliance with these requirements is essential for safe and scalable deployment (General Civil Aviation Authority [GCAA], 2025).

The SDIF therefore encourages organizations to engage proactively with regulators, technology vendors, system integrators, and industry stakeholders. This helps ensure that drone deployment is not only technically feasible, but also legally compliant, operationally safe, and aligned with the wider UAE innovation ecosystem.

4.5 Sustainability Application

Finally, the SDIF is applicable to sustainability and environmental performance. Autonomous drones can support methane monitoring, emissions detection, environmental surveillance, and rapid response to environmental risks. Recent studies show that drone-mounted sensing systems can contribute to methane detection and emissions monitoring, making drones valuable for supporting environmental compliance and sustainability goals (MacGruer et al., 2025; Soskind et al., 2023).

This application is particularly relevant in the UAE, where sustainability and emissions reduction are national priorities. By integrating drone data into environmental monitoring systems and performance dashboards, oil and gas organizations can use drones not only for operational inspection, but also as tools for supporting long-term sustainability and responsible energy production.

5. Conclusion and Future Research

This paper formulated the **Strategic Drone Integration Framework (SDIF)** as a conceptual

model for autonomous drone deployment in the UAE oil and gas sector. The framework addresses the integration chasm by emphasizing the role of integration maturity in achieving digital transformation performance. The SDIF contributes to theory by integrating technical, organizational, and external factors into a unified framework. It contributes to practice by providing a roadmap for scalable and strategic drone deployment.

However, this study is conceptual and lacks empirical validation. Future research should test the framework using **PLS-SEM** and survey data from industry professionals (Hair et al., 2022). Further research may also explore longitudinal analysis, cross-country comparisons, and integration with AI and digital twin technologies. Overall, the SDIF provides a foundation for transforming autonomous drones from operational tools into strategic digital assets in the UAE oil and gas sector.

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