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A Framework for the Mediating Role of Training on the Relationship Between ICT Technology Adoption and Manufacturing Performance in ADNOC UAE

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Abstract

Given ADNOC's strategic push toward digital transformation, it is critical to understand how ICT adoption translates into tangible improvements in manufacturing performance. To address this, the study tested the proposed framework using 356 valid responses from ADNOC employees, analysed through SmartPLS. The model demonstrated strong fit and validity, confirming significant direct effects of biometric systems (0.155), drone technology (0.161), face detection and tracking (0.19), and two-way radio communication (0.18) on manufacturing performance, while robotics showed no direct significance. Training emerged as a critical mediator, fully mediating the effect of robotics and partially mediating the effects of drones, two-way radios, and biometric systems. No mediation was observed for face detection and tracking. These findings highlight the key role of workforce training in unlocking the full potential of ICT technologies, thereby enhancing manufacturing performance in ADNOC's operations.

Keywords: ICT technologies, organizational performance, training

1. Introduction

The adoption of Information and Communication Technology (ICT) has become an essential driver of competitiveness in the manufacturing sector, particularly in knowledge-intensive and high-risk industries such as Oil & Gas. In the UAE, ADNOC has aligned with national digital transformation initiatives by investing in advanced ICT tools to improve operational efficiency, productivity, and innovation (Howard et al., 2025; Alzarooni et al., 2024). These investments include biometric systems for workforce security and accountability, drones for inspection and monitoring, face detection and tracking technologies for safety, robotics for automation, and two-way radios for real-time communication (Aerologix, 2024; Belanche et al., 2020). While such technologies hold immense potential for transforming ADNOC's manufacturing processes, their impact on performance has been inconsistent, raising questions about the factors that condition successful adoption.

Global studies have shown that ICT can significantly improve productivity, efficiency, and quality in manufacturing; however, evidence also points to mixed results, with some cases reporting clear performance gains and others showing limited or no impact (Seidel et al., 2025; Nicolás-Agustín et al., 2025). In ADNOC's context, these inconsistencies are compounded by internal challenges such as weak manufacturing processes, underdeveloped training programs, and gaps in ICT resource utilization (Zaidan, 2017; AlKhoori, 2022). This indicates that ICT investments alone are insufficient to guarantee performance improvements, and that the workforce's ability to integrate and apply these tools plays a decisive role in realizing their benefits.

Training therefore emerges as a critical mediating factor in the ICT–performance relationship. By equipping employees with the technical and operational competencies required to use ICT tools effectively, training ensures that technologies such as drones, robotics, or biometric systems are not underutilized but instead contribute directly to improved productivity, streamlined workflows, and enhanced product quality (Majany et al., 2025; Mehner et al., 2025). Empirical studies further suggest that organizations prioritizing ICT-related training achieve better alignment between technology adoption and performance outcomes, thereby securing greater returns on their digital investments (Sumlin et al., 2025; Enstroem et al., 2025; Nicolás-Agustín et al., 2025).

The proposed framework responds to these challenges by conceptualizing training as the mechanism that links ICT adoption to manufacturing performance. Its effectiveness lies in three key contributions: it explains why ICT outcomes in ADNOC have been inconsistent, provides practical guidance on how employee development can unlock the full potential of ICT, and strengthens ADNOC's strategic alignment with the UAE's broader digital transformation agenda (Alzarooni et al., 2024). Thus, the framework of this study positions training as a strategic bridge between ICT investments and sustainable manufacturing performance, offering both theoretical insights and practical pathways to address ADNOC's pressing operational challenges.

The novelty of this study lies in its sector-specific focus on ADNOC's manufacturing context, integrating multiple ICT technologies; biometric systems, drones, robotics, face detection, and two-way radios; within a single empirical framework. Unlike prior studies that examined ICT adoption or training in isolation, positioning training as a strategic mechanism that links ICT investments to measurable performance improvements. This localized and empirically validated model fills a critical research gap in understanding ICT-driven transformation in the UAE's oil and gas industry.

2. Literature Review

2.1 ICT's Impact on Manufacturing Performance

Information and Communication Technology (ICT) is increasingly recognized as a driver of manufacturing performance, particularly in complex industries such as oil and gas. For ADNOC, ICT tools including two-way radios, drones, biometric systems, face detection technologies, and robotics that are essential for improving communication, operational efficiency, security, and productivity (Alzarooni et al., 2024; Al-Qubaisi et al., 2018). Two-way radios support real-time coordination in drilling and maintenance operations (Papazafeiropoulos et al., 2025), while drones enhance infrastructure surveillance and safety through remote monitoring (Aerologix, 2024). Biometric and face detection systems strengthen access control and safety compliance, reducing risks of unauthorized entry and workplace accidents (Edoh et al., 2023; Fahim et al., 2025). Robotics further contribute by automating hazardous or repetitive tasks, increasing precision, and reducing labour exposure (Belanche et al., 2020).

However, studies highlight persistent challenges at ADNOC, such as limited integration of ICT with existing processes and gaps in workforce readiness, which restrict the realization of full performance benefits (Zaidan, 2017; AlKhoori, 2022). This suggests that technology adoption alone is insufficient; employee training acts as a mediating factor that enables the workforce to leverage ICT tools effectively, thereby translating digital investments into measurable gains in efficiency, safety, and quality. Strengthening this linkage positions ADNOC to sustain competitiveness and advance its digital transformation agenda in the UAE's oil and gas sector (Alzarooni et al., 2024; Al-Qubaisi et al., 2018).

2.2 Training in ICT to Enhance Manufacturing Operations

Training is a critical element of Human Resource Management (HRM) that directly influences organizational and manufacturing performance. In technology-driven industries, such as oil and gas, ICT training equips employees with the skills and competencies required to operate advanced systems, including automation, robotics, and AI-enabled applications (Kholidah et al., 2023). Within manufacturing, such training enhances productivity by streamlining workflows, minimizing operational errors, and supporting informed decision-making, which collectively improve output quality and efficiency. Moreover, effective ICT training fosters adaptability and innovation, enabling employees to embrace new technologies and address operational challenges with agility (Mehner et al., 2025).

For ADNOC, where digital transformation is reshaping manufacturing and operational processes, ICT training plays a pivotal mediating role by ensuring that investments in digital tools translate into tangible performance outcomes. By prioritizing workforce development, ADNOC can strengthen employee readiness to utilize ICT systems effectively, thereby enhancing efficiency, safety, and competitiveness in the global energy sector. Ultimately, ICT training is not merely about sustaining routine operations but about positioning the organization for long-term success in a highly digitalized industrial landscape, offering sustainable advantages in productivity, quality, and innovation (Sumlin et al., 2025).

2.3 Organizational Manufacturing Performance Through ICT Application

The adoption of ICT plays a pivotal role in enhancing manufacturing performance by streamlining processes, improving communication, and enabling innovation. Through the integration of digital tools, organizations can optimize data collection, analysis, and dissemination, which supports informed decision-making and better alignment between operational goals and performance outcomes (Enstroem et al., 2025). Automation of key processes reduces costs, minimizes human errors, and increases production throughput, thereby boosting operational efficiency and ensuring consistent product quality. ICT also fosters innovation not only in manufacturing methods but in strategic and business models, with systems such as Enterprise Resource Planning (ERP) enhancing supply chain coordination, inventory management, and production planning to ensure optimal resource utilization.

Furthermore, ICT strengthens performance measurement by enabling real-time monitoring of metrics such as output levels, machine efficiency, and product quality. These indicators provide valuable insights into growth opportunities while signalling areas requiring operational improvement (Enstroem et al., 2025). By leveraging ICT for both operational optimization and strategic monitoring, organizations can achieve significant improvements in productivity, adaptability, and sustainability. For companies such as ADNOC, this integration ensures that manufacturing processes remain competitive, resilient, and responsive to evolving market demands, ultimately securing long-term performance and global competitiveness (Nicolás-Agustín et al., 2025; Kaniz et al., 2025).

3. Development of Conceptual Framework

The proposed framework positions training as a mediator between ICT adoption and manufacturing performance in ADNOC. While ICT tools such as biometric systems, drones, robotics, face detection, and two-way radios provide technological capabilities, their effectiveness in improving productivity, efficiency, and quality depends on employees' ability to use them effectively (Majany et al., 2025; Nicolás-Agustín et al., 2025). Prior research shows mixed evidence on ICT's direct impact on performance, largely because many models overlook the role of workforce capabilities in translating technology into outcomes (Seidel et al., 2025; Nicolás-Agustín et al., 2025).

Grounded in Resource Dependency Theory (RDT), which stresses the reliance of organizations on external resources such as technology and skills to achieve goals (Cheng et al., 2025), the framework emphasizes that ICT adoption alone is insufficient. Training is the critical resource that enables employees to maximize ICT benefits, reduce operational errors, and drive innovation. To explain this interaction, the study applies mediation models such as those proposed by Baron and Kenny and further developed by Preacher and Hayes in Said et al., (2023), which offer structured methods to examine how training strengthens the ICT–performance link.

Through integrating RDT with mediation analysis, the framework addresses gaps in earlier ICT–performance models and clarifies why results have been inconsistent. It argues that ICT improves performance in ADNOC's manufacturing operations only when supported by adequate training, thereby ensuring sustainable efficiency, innovation, and competitiveness in line with UAE's digital transformation goals (Alzarooni et al., 2024; Faishal et al., 2025; Bello et al., 2025). Figure 1 illustrates these relationships, highlighting the central role of training in shaping ICT-driven performance outcomes.

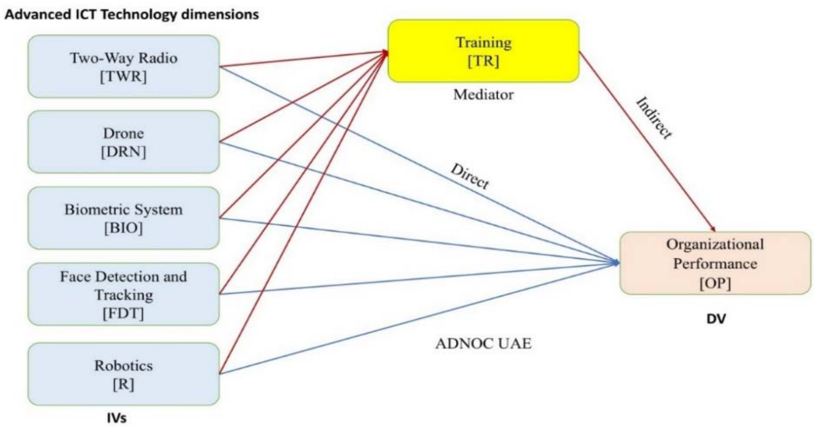

Figure 1. The Proposed conceptual framework

Figure 1 highlights ICT technologies as essential drivers of manufacturing performance at ADNOC, where systems such as biometrics, drones, face detection and tracking, robotics, and two-way radios enable greater innovation, efficiency, and operational effectiveness. These tools enhance productivity and streamline processes, ultimately improving cost-effectiveness and product quality (Al-Qubaisi et al., 2018; Aerologix, 2024). To sustain such performance, training is crucial in equipping employees with the skills to effectively operate and integrate these technologies into daily operations.

Through strengthening employee expertise, training reduces downtime, minimizes operational errors, and ensures that ICT adoption translates into tangible manufacturing improvements (Nicolás-Agustín et al., 2025; Mehner et al., 2025). Consequently, ICT-driven manufacturing performance at ADNOC depends not only on the availability of advanced technologies but also on the organization's ability to invest in human capital through targeted training programs (Alzarooni et al., 2024; AlKhoori, 2022).

4. Modelling Analysis

Methodologically, this study is novel in combining Resource Dependency Theory (RDT) with quantitative validation through Partial Least Squares Structural Equation Modelling (PLS-SEM). This hybrid approach strengthens the theoretical foundation while providing empirical evidence of the mediating role of training. It allows for simultaneous evaluation of direct and indirect effects across multiple ICT technologies, offering a more integrated and data-driven assessment of how workforce development enhances manufacturing performance within ADNOC.

The conceptual framework was rigorously analysed using data from a questionnaire survey of ADNOC employees, employing SmartPLS software. SmartPLS applies Partial The conceptual framework was analysed using questionnaire data from 356 valid responses of ADNOC employees through SmartPLS, which applies Partial Least Squares Structural Equation Modelling (PLS-SEM). This method, suited for complex models and smaller samples, simultaneously evaluates construct reliability and validity in the measurement model and examines interrelationships in the structural model (Joseph et al., 2017).

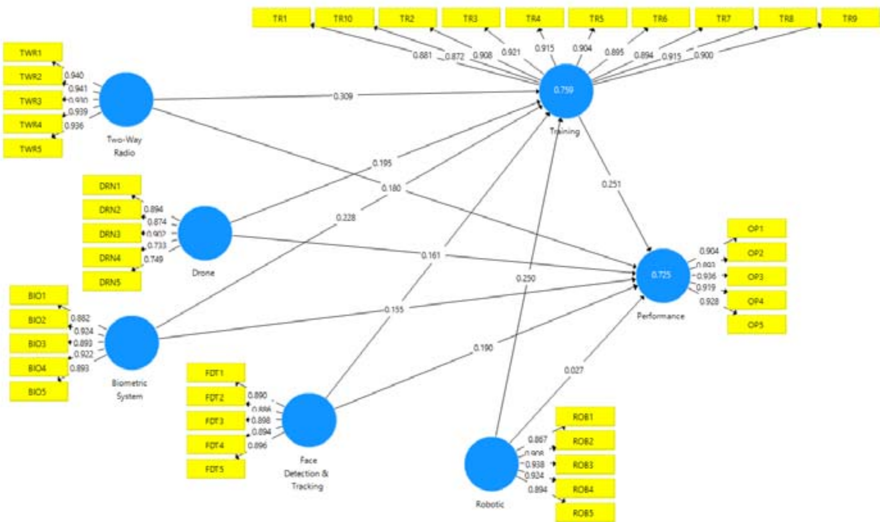

Figure 2. Output of path analysis

4.1 Assessment of Measurement Model

The assessment of the measurement model involved evaluating two key criteria: Construct Reliability and Validity (CRV) and Discriminant Validity. These criteria are examined to ensure that the measurement items are both reliable and valid representations of their respective constructs. The detailed procedures and results of these assessments are elaborated in the following subsections.

4.1.1 Construct Reliability and Validity (CRV)

Construct reliability, assessed through composite reliability and Cronbach's alpha, ensures consistent measurement by minimizing random error. Construct validity, measured via convergent and discriminant validity, evaluates how well constructs capture their intended targets. Table 1 summarizes the reliability and validity results from the PLS Algorithm (Joseph et al., 2017).

Table 1. The generated of CRV results

Constructs	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Biometric System_	0.943	0.957	0.815
Drone	0.888	0.919	0.695
Face Detection & Tracking	0.936	0.952	0.797
Performance	0.952	0.963	0.839
Robotic	0.946	0.958	0.822
Training	0.974	0.977	0.811
Two-Way Radio_	0.965	0.973	0.878

Table 1 confirms strong construct reliability and validity, with Cronbach's Alpha and Composite Reliability values exceeding 0.70, indicating high internal consistency. Average Variance Extracted (AVE) values are above 0.50, confirming convergent validity, with Biometric System (0.815), Performance (0.839), and Two-Way Radio (0.878) showing particularly high validity. Overall, the measurement model demonstrates strong reliability and suitability for further analysis.

4.1.2 Discriminant Validity

Discriminant validity ensures that each construct is conceptually distinct, confirming it measures a unique factor within the model. It is typically assessed using the Fornell–Larcker criterion and the Heterotrait–Monotrait (HTMT) ratio, which compare correlations to validate construct distinctiveness (Joseph et al., 2017; Migni et al., 2025). Table 2 presents the discriminant validity results derived from the PLS Algorithm analysis.

Table 2. Results of Fornell and Larcker

Construct	[a]	[b]	[c]	[d]	[e]	[f]	[g]
Biometric System [a]	0.903						
Drone [b]	0.790	0.834					
Face Detection & Tracking [c]	0.628	0.691	0.893				
Performance [d]	0.736	0.774	0.707	0.916			
Robotic [e]	0.689	0.746	0.692	0.696	0.906		
Training [f]	0.765	0.798	0.66	0.785	0.757	0.901	
Two-Way Radio [g]	0.688	0.771	0.687	0.756	0.668	0.781	0.937

Table 2 reports the Fornell–Larcker results for constructs including Biometric System, Drone, Face Detection & Tracking, Performance, Robotics, Training, and Two-Way Radio. The diagonal values (square roots of AVE) exceed inter-construct correlations, confirming strong discriminant validity (Joseph et al., 2017). This indicates that each construct is more strongly related to its own measures than to others, validating their distinctiveness. Complementing this, Table 3 presents the Heterotrait–Monotrait (HTMT) ratios, a stricter criterion that further confirms discriminant validity in the PLS Algorithm analysis (Joseph et al., 2017).

Table 3. Results of Heterotrait-Monotrait (HTMT)

Construct	[a]	[b]	[c]	[d]	[e]	[f]	[g]
Biometric System [a]							
Drone [b]	0.861						
Face Detection & Tracking [c]	0.668	0.757					
Performance [d]	0.776	0.84	0.748				
Robotic [e]	0.729	0.814	0.735	0.733			
Training [f]	0.798	0.855	0.691	0.815	0.788		
Two-Way Radio [g]	0.72	0.832	0.722	0.788	0.698	0.805	

Table 3 presents the Heterotrait–Monotrait (HTMT) ratios for constructs such as Biometric System, Drone, Face Detection & Tracking, Performance, Robotics, Training, and Two-Way Radio. The ratios range from 0.668 to 0.861, all below the 0.90 threshold, confirming discriminant validity and demonstrating that each construct measures a unique concept (Joseph et al., 2017; Migni et al., 2025).

4.2 Assessment of Structural Model

The assessment of the structural model involved the evaluation of several key criteria, including the coefficient of determination (R^2), effect size (f^2), model fit indices, hypotheses of direct relationships, hypotheses of indirect relationships, and predictive relevance. These aspects are systematically examined and discussed in the following subsections.

4.2.1 R Square Values

An R^2 value of 0.02 is generally interpreted as weak, 0.13 as moderate, and 0.26 or higher as substantial in terms of explanatory power. Accordingly, an R^2 value of 0.10 or above may be considered adequate for evaluating the reliability of multivariate models (Migni et al., 2025).

Table 4. Results of R- square values

Name of construct	Endogenous	R Square
Performance	Dependent variable	0.725
Training	Mediator	0.759

Table 4 shows the variance explained by the predictors, with Performance (R^2 = 0.725) and Training (R^2 = 0.759) indicating that 72.5% and 75.9% of their variance, respectively, are explained by the model. These high R^2 values reflect strong explanatory power, confirming the predictors' effectiveness in accounting for variability in both constructs (Joseph et al., 2017; Migni et al., 2025).

4.2.2 f-square Values

Table 5 shows the results of the f^2 effect size. The f^2 complements R^2 by evaluating the significance and relevance of each predictor, with thresholds of 0.02 (small), 0.15 (medium), and 0.35 (large) (Joseph et al., 2017; Migni et al., 2025).

Table 5. Results of f square values

Constructs	**Performance [DV]**	**Training [Mediator]**
Biometric System	0.028	0.074
Drone	0.022	0.038
Face Detection & Tracking	0.055	0.000
Performance	-NA-	-NA-
Robotic	0.001	0.095
Training	0.055	-NA-
Two-Way Radio	0.036	0.138

Table 5 reports the effect sizes (f^2) of predictors on Performance and Training. Most predictors show small effects, including Biometric System, Drone, and Face Detection & Tracking on Performance (0.028, 0.022, 0.055) and Biometric System, Drone, and Robotics on Training (0.074, 0.038, 0.095). Robotics exerts negligible influence on Performance (0.001), while Face Detection & Tracking has no effect on Training. Training itself shows a small effect on Performance (0.055). Notably, Two-Way Radio demonstrates a small effect on Performance (0.036) but a moderate effect on Training (0.138), emerging as the strongest predictor. These results align with f^2 interpretation thresholds (Joseph et al., 2017; Migni et al., 2025), underscoring the distributed yet significant contributions of ICT tools and Training to ADNOC's manufacturing performance.

4.2.3 Model Fit

Model fit evaluates how effectively the statistical model represents the data. Table 6 shows the results of model fit generated values.

Table 6. Results of model

Model fit items	Saturated Model	Estimated Model
SRMR	0.045	0.045
d_ULS	1.63	1.63
d_G	2.181	2.181
Chi-Square	3891.918	3891.918
NFI	0.805	0.805

Table 6 presents the model fit results, confirming robustness and reliability. The SRMR value of 0.045 indicates a good fit, meeting the <0.08 threshold. The d_ULS (1.63) and d_G (2.181) values for both Saturated and Estimated models demonstrate consistency and adequacy (Bello et al., 2025). Although the Chi-Square statistic (3891.918) supports overall fit, it is interpreted cautiously due to sample size sensitivity. Finally, the NFI value of 0.805, exceeding the 0.80 benchmark, further validates model adequacy (Joseph et al., 2017; Migni et al., 2025). Collectively, these indices confirm the framework's strong performance and suitability for analysis.

4.2.4 Hypothesis of Direct Relationship

Hypothesis testing was conducted using the bootstrapping procedure to examine the direct relationships proposed in the research model. This analysis aimed to assess the significance and strength of the hypothesized structural paths between the constructs. The results of the direct relationship analysis are presented in Table 7.

Table 7. Direct relationships of the model

Direct relationship	Path strength	T >1.96	Remarks
Biometric System_-> Performance	0.155	2.070	Significant
Drone -> Performance	0.161	2.024	Significant
Face Detection & Tracking -> Performance	0.190	3.190	Significant
Robotic -> Performance	0.027	0.457	Not significant
Two-Way Radio -> Performance	0.180	2.501	Significant

Table 7 shows that biometric systems, drones, face detection & tracking, and two-way radios significantly enhance organizational performance, supported by positive path strengths and significant T-statistics. Among these, face detection & tracking exerts the strongest influence (path = 0.19, T = 3.19), while robotics demonstrates minimal impact (path = 0.027, T = 0.457). These findings emphasize the importance of prioritizing ICT technologies with the greatest performance impact, guiding ADNOC UAE toward more strategic resource allocation and improved manufacturing outcomes (Al-Qubaisi et al., 2018).

4.2.5 Hypothesis of Indirect Relationship

Hypothesis testing was conducted to examine the indirect relationships proposed in the research model. The analysis aimed to assess the mediating effects among the constructs by evaluating the significance of the indirect paths using the bootstrapping procedure. The results of the indirect relationship analysis are presented in Table 8.

Table 8. Results of indirect path relationship analysis

Indirect path relationship	Path strength	T >1.96	Remarks
Face Detection & Tracking -> Training -> Performance	-0.001	0.069	Not significant
Drone -> Training -> Performance	0.049	2.133	Significant
Two-Way Radio -> Training -> Performance	0.078	2.641	Significant
Biometric System -> Training -> Performance	0.057	2.334	Significant
Robotic -> Training -> Performance	0.063	2.27	Significant

Table 8 shows that Training significantly mediates the effects of Drones, Two-Way Radios, Biometric Systems, and Robotics on Performance, while Face Detection & Tracking demonstrates no meaningful indirect effect. The mediation effects are reinforced by strong path coefficients and significant T-statistics, underscoring Training's critical role in amplifying technology-driven performance outcomes.

4.2.6 Predictive Relevance

Predictive relevance was assessed using Construct Cross-Validated Redundancy (CVR) and Construct Cross-Validated Communality (CVC), represented by Q^2 values. These metrics evaluate the model's ability to forecast omitted data points, where values above 0 indicate predictive relevance. Together, CVR and CVC confirm the model's robustness and practical applicability (Said et al., 2023).

Table 9. Results of Construct Cross validated redundancy (CVR)

Construct	SSO	SSE	Q^2 (=1-SSE/SSO)
Biometric System	1780	1780	
Drone	1780	1780	
Face Detection & Tracking	1780	1780	
Performance	1780	707.255	0.603
Robotic	1780	1780	
Training	3560	1398.765	0.607
Two-Way Radio	1780	1780	

Table 9 presents the CVR for endogenous construct, thus the Performance (Q^2 = 0.603) and Training (Q^2 = 0.607) exhibiting moderate predictive relevance.

Table 10. Results of Construct Cross validated Communality (CVC)

Constructs	**SSO**	**SSE**	**Q^2 (=1-SSE/SSO)**
Biometric System	1780	512.308	0.712
Drone	1780	818.371	0.54
Face Detection & Tracking	1780	560.736	0.685
Performance	1780	449.667	0.747
Robotic	1780	496.331	0.721
Training	3560	856.758	0.759
Two-Way Radio	1780	349.787	0.803

Table 10 presents the Construct Cross-Validated Communality (CVC) metrics for exogenous and endogenous constructs. he Q^2 values span from 0.54 to 0.803, with elevated values indicating superior predictive relevance. The Two-Way Radio and Training demonstrate substantial predictive relevance, whereas Drone exhibits moderate predictive relevance, underscoring the efficacy and applicability of these constructs in forecasting performance outcomes.

4.3 Mediation Effect

Mediation effects occur when an independent variable influences a dependent variable through a mediator. Partial mediation means the mediator explains part of the relationship while a direct link remains, whereas full mediation eliminates the direct connection entirely. Researchers commonly employ the Baron and Kenny method, the Sobel test, or bootstrapping techniques to evaluate mediation effects and ascertain the significance of indirect effects (Said et al., 2023).

Table 11. Results of mediation effect

Indirect relationship	**Remarks**	**Direct relationship**	**Remarks**	**Decision**
Face Detection & Tracking -> Training -> Performance	Not significant	Face Detection & Tracking -> Performance	Significant	No effect
Drone -> Training -> Performance	Significant	Drone -> Performance	Significant	Partial effect
Two-Way Radio_ -> Training -> Performance	Significant	Two-Way Radio -> Performance	Significant	Partial effect
Biometric System -> Training -> Performance	Significant	Biometric System_-> Performance	Significant	Partial effect
Robotic -> Training -> Performance	Significant	Robotic -> Performance	Not significant	Full effect

According to Table 11, the mediation effects in the relationship between Face Detection & Tracking and Performance indicate that the indirect path through Training is not significant, while the direct path is significant. This signifies that Training does not mediate the relationship between Face Detection & Tracking and Performance, indicating the absence of a mediation effect.

The high R^2 and Q^2 values, combined with strong model fit indices (SRMR < 0.08, NFI > 0.80), empirically confirm the effectiveness of the proposed framework in explaining and predicting manufacturing performance outcomes. This demonstrates that integrating training as a mediating variable substantially enhances the predictive capability of ICT adoption models, validating the framework's robustness and practical applicability for ADNOC's digital transformation initiatives.

5. The Empirical Framework

An empirically validated framework is a structured model rigorously tested and confirmed using real-world manufacturing data, ensuring its reliability and practical applicability in improving manufacturing performance across various sectors. Figure 3 provides a visual representation of this framework.

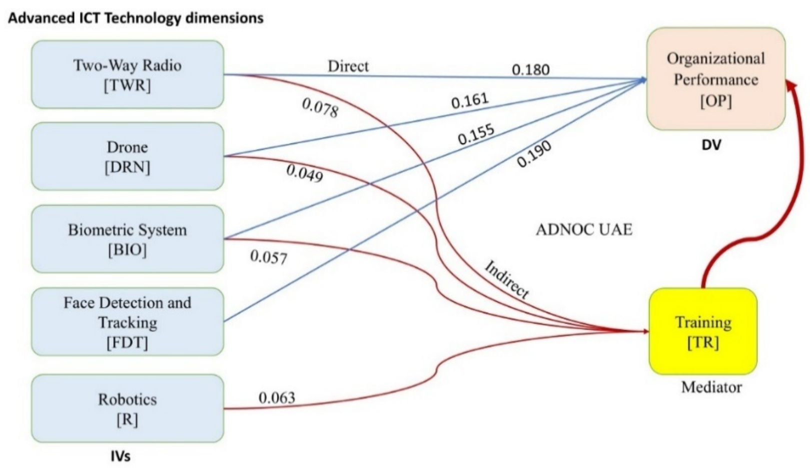

Figure 3. Empirical framework of the study

The framework in Figure 3 illustrates both the direct relationships between independent variables (IVs), such as ICT technologies (Biometric Systems, Drones, Face Detection & Tracking, Robotics, Two-Way Radios), and the dependent variable (DV), which in this case is manufacturing performance (Howard et al., 2025). It also shows the indirect relationships through training as a mediator to the DV (Nicolás-Agustín et al., 2025).

For direct relationships, all IVs, except robotics, demonstrate significant relationships with manufacturing performance (DV) (Majany et al., 2025). The strongest path is from Face Detection & Tracking to manufacturing performance, with a beta value of 0.190 (Mimouni &

Mouna, 2025). Regarding the indirect relationships, all IVs, except face detection & tracking, show significant effects (Seidel et al., 2025). The strongest indirect relationship comes from Two-Way Radios, with a beta strength of 0.078 (AlKhoori, 2022).

In terms of mediation effects, for Two-Way Radios, Drones, and Biometric Systems, both direct and indirect relationships are significant, indicating that training plays a partial mediation effect in enhancing manufacturing performance (Alzarooni et al., 2024). However, for Face Detection & Tracking, only the direct relationship is significant, meaning that training does not mediate the effect (Mimouni & Mouna, 2025). In contrast, for Robotics, only the indirect relationship is significant, meaning that training has a full mediation effect, highlighting its critical role in improving manufacturing performance through effective technology use (Majany et al., 2025).

The integration of these ICT technologies provides ADNOC with multiple operational and strategic benefits in its manufacturing and energy operations. Biometric systems enhance workforce authentication and safety compliance, reducing human error and ensuring that only certified personnel operate sensitive equipment (Papazafeiropoulos et al., 2025). Drones allow real-time monitoring of remote manufacturing sites and pipelines, leading to improved inspection efficiency, cost reduction, and enhanced predictive maintenance capabilities (Alzarooni et al., 2024). Face Detection & Tracking strengthens site security and workforce monitoring, ensuring regulatory compliance and operational integrity (Mimouni & Mouna, 2025). Robotics contributes indirectly through training and automation of high-risk tasks, minimizing accidents and ensuring consistent product quality in manufacturing processes (Majany et al., 2025). Finally, Two-Way Radios improve communication efficiency between dispersed teams, enabling quick decision-making, faster incident response, and better coordination across ADNOC’s complex manufacturing operations (AlKhoori, 2022).

5.1 Application to Other Industry

While the empirical framework was validated using manufacturing data, its structure and findings demonstrate strong potential for application across other industries where ICT technologies and training play pivotal roles in enhancing organizational performance. The framework’s emphasis on both direct and mediated relationships provides a versatile model that can be adapted to diverse operational contexts.

In the healthcare sector, biometric systems can be employed to ensure patient safety and secure access to medical records, thereby reducing risks of data breaches and unauthorized interventions. Drones, already proven effective in manufacturing inspections, can be repurposed for rapid delivery of medical supplies to remote areas, improving emergency response times and supply chain resilience. Face Detection & Tracking technologies can strengthen hospital security and patient monitoring, ensuring compliance with safety protocols. Robotics, with its full mediation effect through training, can be leveraged for surgical assistance and repetitive clinical tasks, where staff training ensures safe and effective deployment. Two-Way Radios, as demonstrated in manufacturing, can enhance communication among emergency teams, enabling faster coordination during critical incidents.

In the construction industry, biometric systems can regulate site access, ensuring that only certified workers operate heavy machinery. Drones can provide real-time monitoring of construction progress and safety compliance, reduce inspection costs, and improve project oversight. Face Detection & Tracking can support workforce attendance monitoring and site security. Robotics, mediated through training, can automate high-risk tasks such as demolition or material handling, thereby reducing accidents. Two-Way Radios remain vital for coordinating dispersed teams across large construction sites, ensuring timely communication between engineers, supervisors, and workers.

Similarly, in the energy and utilities sector, drones can monitor pipelines and power lines, enhancing predictive maintenance and reducing downtime. Biometric systems can secure access to critical infrastructure, while robotics can automate hazardous tasks such as equipment repair in high-risk environments. Face Detection & Tracking ensures compliance with safety regulations in restricted zones, and Two-Way Radios facilitate rapid communication during outages or emergencies.

Overall, the empirical framework demonstrates adaptability beyond manufacturing, offering a structured approach for integrating ICT technologies with training to improve performance outcomes. By recognizing the varying degrees of direct and mediated effects across technologies, industries can tailor their strategies to maximize operational efficiency, safety, and resilience. This cross-sector applicability underscores the framework's robustness and its potential contribution to advancing digital transformation across multiple domains.

6. Conclusion

This study has developed a comprehensive framework to enhance manufacturing performance through the strategic adoption of ICT technologies and the implementation of effective training programs. The results revealed that, for direct relationships, all independent variables (IVs) except robotics demonstrated significant relationships with manufacturing performance (DV). The strongest direct effect was observed for Face Detection & Tracking, with a beta value of 0.190, highlighting its significant contribution to improving manufacturing operations.

For indirect relationships, all IVs except face detection & tracking showed significant effects, with the strongest indirect path originating from Two-Way Radios, yielding a beta value of 0.078. This demonstrates the important role of communication technologies in enhancing manufacturing efficiency and coordination.

Regarding mediation effects, training exhibited partial mediation for Two-Way Radios, Drones, and Biometric Systems, as both direct and indirect relationships were significant. This indicates that effective training programs help optimize the use of these ICT technologies, leading to improved manufacturing performance. For Face Detection & Tracking, only the direct relationship was significant, suggesting that training does not mediate the effect of this technology on performance. In contrast, for Robotics, only the indirect relationship was significant, indicating that training has a full mediation effect, emphasizing its critical role in enabling robotics to enhance manufacturing efficiency and productivity.

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