“Digital customs regulations and digital transformation as drivers of job proficiency in Peruvian customs agencies: The mediating role of professional competencies (PLS-SEM)”

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DIGITAL CUSTOMS REGULATIONS AND DIGITAL TRANSFORMATION AS DRIVERS OF JOB PROFICIENCY IN PERUVIAN CUSTOMS AGENCIES: THE MEDIATING ROLE OF PROFESSIONAL COMPETENCIES (PLS-SEM)

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Abstract

Digital transformation is central to customs modernization, yet empirical evidence on how regulatory digitization translates into employees' job proficiency through capability-building remains limited in Peru. This study aims to test the relationships among digital customs regulations, digital transformation, professional competencies, and job proficiency in Peruvian customs agencies, including the mediating role of professional competencies, using PLS-SEM. A quantitative explanatory–predictive, cross-sectional design was applied. Data were collected via a five-point online survey of 104 employees in Peruvian customs agencies (Lima–Callao) in October–November 2025, recruited through WhatsApp-based convenience/snowball sampling. The model was estimated in ADANCO 2.4.1 with a two-stage approach for the higher-order digital transformation construct and bootstrap inference. Digital customs regulations strongly predicted digital transformation ($\beta = 0.872$, $p < 0.001$) and generated a sizeable total indirect effect on job proficiency ($\beta = 0.757$, $p < 0.001$). Digital transformation increased professional competencies ($\beta = 0.853$, $p < 0.001$) and had a direct effect on job proficiency ($\beta = 0.464$, $p = 0.026$), while professional competencies also enhanced job proficiency ($\beta = 0.473$, $p = 0.023$). Mediation was supported for the pathway digital transformation → competencies → job proficiency ($\beta\_ind = 0.403$, $p = 0.034$), yielding a total digital transformation effect of $\beta = 0.867$. Explanatory power was high (R^2: DT = 0.761; competencies = 0.725; job proficiency = 0.814; SRMR = 0.041). The findings indicate that regulatory-driven digitization improves work proficiency primarily when accompanied by systematic competency development, highlighting training and institutional enablers as priorities in customs reform.

Keywords digitization, proficiency, competence, customs, regulation, mediation, PLS-SEM

JEL Classification O33, M15, J24, D24

INTRODUCTION

Rapid digitization in business and government, alongside AI, is reshaping work, promising productivity while exposing Latin America's gaps in capabilities, skills, and culture (Chávez-Díaz et al., 2024; International Monetary Fund, 2024). In Peru, process-intensive services are constrained by interoperability, data quality, and compliance.

The COVID-19 pandemic intensified this trend by speeding up digital adoption while straining work systems, with measurable effects on employee performance and labor productivity (Contreras-Yupanqui, 2025). Evidence from Peruvian organizations links digital transformation to job performance, although results depend on digital com-

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petencies and complementary human capital (Arias Gonzales et al., 2024; Medina-Esquivel et al., 2024). In customs intermediation, digitization shapes time and cost outcomes; a Peruvian agency reported a strong correlation with labor productivity during the pandemic (Estrada Izquierdo, 2024).

Nevertheless, the scientific problem remains insufficiently resolved: existing studies in the region often report associations but provide limited causal explanation of the mechanisms through which digital transformation (and the regulatory digitization that enables or constrains it) translates into job proficiency in customs agencies. Moreover, evidence from other Peruvian sectors suggests that the effects of digitization are intertwined with skills and organizational enablers (Espina-Romero et al., 2024), which points to the need to model these pathways explicitly in the customs context.

1. LITERATURE REVIEW AND HYPOTHESES

1.1. Related theories

The theory of dynamic capabilities, proposed by Teece et al. (1997), is one of the main conceptual frameworks for analyzing digital transformation. This theory explains how organizations develop internal capabilities to integrate, build, and reconfigure resources in constantly changing environments. In the context of customs agencies, these dynamic capabilities are reflected in the adoption of digital tools, process automation, and organizational adaptation to changing technological and regulatory environments. According to Zhang and Dong (2023), the quality of internal control and digital management capabilities strengthens total factor productivity, demonstrating that digital transformation is not only a technological phenomenon but also a strategic competency that increases institutional efficiency.

For its part, the theory of resource-based view, developed by Barney (1991), argues that an organization's sustainable competitive advantage comes from the proper management of its valuable, rare, inimitable, and non-substitutable resources. From this perspective, digital resources (such as technological infrastructure, automation systems, and staff skills) represent strategic assets that drive labor productivity. Wang and Han (2023) showed that service-oriented digitization improves organizational productivity by optimizing processes, reducing time, and increasing the effectiveness of operations. Therefore, digital transformation, as an organizational resource, is directly associated with efficiency and work effectiveness in customs agencies.

Finally, the theory of organizational learning, developed by Argyris and Schön (1978), complements the previous ones by highlighting the importance of adaptation and continuous feedback within institutions. This theory argues that organizations that learn from their experiences can respond more effectively to technological changes. In the context of digital transformation, knowledge generation, ongoing training, and cultural adaptation of workers become essential elements for improving productivity. According to Contreras-Yupanqui (2025), digital skills are the most influential factor in institutional productivity in the Peruvian public sector, confirming that organizational learning acts as a mediator between digitization and job performance.

1.2. Digital transformation

In academic terms, digital transformation is defined as the process of cross-cutting integration of digital technologies across all areas of an organization, fundamentally reconfiguring its operational processes, structure, and the mechanisms through which it creates and delivers value to customers. It therefore involves a structural organizational change that emphasizes the role of technology in improving performance, expanding reach, and optimizing results (Chang et al., 2022; Geada, 2021; Paiithannkar & Alexander, 2025).

Among the key features of digital transformation are the integration of various types of digital technologies, such as artificial intelligence, the Internet of Things, cloud computing, and big data analytics, which are incorporated into processes, products, and services to enhance efficiency and drive innovation (Dokuchaev, 2020; Haktanır et al., 2023; Savchuk et al., 2024). On the other hand,

there is profound organizational change that requires reconfiguring culture, workflows, and business models, so that the transformation is not limited to technology, but involves rethinking how the organization operates and relates to its customers (Alloghani et al., 2022; Haktanır et al., 2023).

In terms of performance and competitiveness, digital transformation seeks to create flexible, innovative, and adaptive organizations capable of responding quickly to changes in the environment and meeting customer needs (Chang et al., 2022; Savchuk et al., 2024); consistently, it aims to increase business performance and maintain competitive advantages over time (Chang et al., 2022; Haktanır et al., 2023). Its impact also varies across sectors (automotive, energy, healthcare, banking, among others) due to differences in processes, regulatory frameworks, and value chain structures (Alloghani et al., 2022; Kuntonbutr et al., 2019). Each industry faces specific implementation challenges (technological capabilities, change management, interoperability) and unique opportunities to capture value from digital technology (Alloghani et al., 2022; Kuntonbutr et al., 2019).

In risk management, the incorporation of new technologies amplifies exposure to unauthorized access and breaches of confidentiality, making security governance, including continuous threat assessment, access controls, encryption, and response plans, a critical component of digital transformation (Dokuchaev, 2020). Consequently, organizations must develop and adopt specific approaches and capabilities to effectively manage these risks, articulating policies, frameworks, and metrics that accompany the innovation lifecycle (Dokuchaev, 2020). Likewise, digital transformation is usually deployed in three sequential phases (initial readiness, intermediate implementation, and innovative disruption), each with different challenges in terms of strategic alignment, process redesign, skills development, and change management, which require specific strategies and capabilities for proper execution and sustainability (Tian & Ou, 2024).

A people-centered approach is crucial to the success of digital transformation, insofar as the articulation between human-computer interaction and software engineering allows for the design of systems that are not only technically robust but also usable, inclusive, and oriented toward the real needs of users. In this context, organizational agility, sustainability, ethical considerations, and cybersecurity are equally relevant as guiding principles for technological design and implementation (Ardito et al., 2023).

1.3. Job proficiency

Job proficiency has emerged as a central construct in research on performance, employability, and competitiveness in the contemporary labor market. Its relevance has intensified in the face of digital transformation, globalization, and the growing demand for complex and adaptive competencies in all productive sectors (Bradbury & Sturm, 2024; Drolas, 2010; Fernando et al., 2025). Understanding job proficiency is essential for organizations seeking to optimize their human capital, for workers aspiring to mobility and professional development, and for education systems that must align their training offerings with market needs. Literature converges in describing it as the integration of knowledge, skills, attitudes, and values that enable individuals to perform their job functions effectively (Johari & Jha, 2021; Wu et al., 2024).

Likewise, job proficiency is an inherently multidimensional construct. Its configuration tends to vary depending on the sector of activity and the level of qualification required, so that it can integrate, first and foremost, cognitive dimensions associated with analysis, reasoning, problem solving, and critical thinking, which are consistently linked to job quality and income (Acosta et al., 2020; Fernando et al., 2025). Secondly, technical skills are related to the mastery of tools, processes, and technologies specific to the position, including manual and digital skills, that enable tasks to be performed efficiently and accurately (Kotake et al., 2018; Sewu & Sirait, 2017). Additionally, socio-emotional dimensions encompass interpersonal skills such as communication, teamwork, adaptability, leadership, and emotional intelligence, which are fundamental for performance in dynamic organizational environments (Payan-Carreira et al., 2019; Silva et al., 2020). Finally, physical components are linked to sensorimotor coordination, dexterity, and endurance, which

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are particularly relevant in sectors where physical performance is critical, such as manufacturing and healthcare (Cotterill & Simpson, 2018; Kotake et al., 2018).

Various individual and organizational factors influence job proficiency, among which seniority tends to show a positive, albeit moderate, association, which tends to intensify in more highly skilled occupations (Jay & Copes, 1957). Complementarily, the work environment, including conditions such as the degree of isolation, the variety of competencies required, the quality of available equipment, and the level of organizational support, is related to productivity, satisfaction, and the risk of occupational burnout, creating a framework that can enhance or limit performance (Jiang et al., 2018; Stinchcomb & Leip, 2013; Voll & Pfnür, 2024). Likewise, motivation and learning processes are decisive, insofar as informal learning opportunities, control over tasks, and organizational support favor capacity development and, consequently, sustained increases in proficiency (Mikkelsen & Olsen, 2019).

The effect of contextual factors on job proficiency manifests itself primarily through workplace isolation, which tends to erode confidence, commitment, and performance, especially in teleworking arrangements, although the quality of communication and social support can partially mitigate these effects (Mikkelsen & Olsen, 2019; Mulki et al., 2008; Peng et al., 2023). Secondly, the quality and availability of equipment, as well as the presence of adequately qualified personnel, are enabling conditions for performance, insofar as they facilitate the efficient execution of tasks and the achievement of project objectives. Finally, organizational support consistently contributes to improving satisfaction and commitment, and to raising performance through mechanisms such as strengthening psychological capital and identification with the organization (Aggarwal, 2024; Chen et al., 2024; Sihag, 2020; Zhang & Ma, 2020).

Taken together, prior research suggests that digital transformation can enhance work outcomes, yet it also indicates that institutional enablers and workforce capabilities condition whether these gains materialize and persist. In customs intermediation – where compliance, traceability, and standardized procedures are central – the mechanisms linking regulatory digitization to job proficiency remain insufficiently modeled with causal–predictive evidence.

This study aims to model and empirically test the relationships among digital customs regulations, digital transformation, professional competencies, and job proficiency in Peruvian customs agencies, as well as the mediating role of professional competencies, using PLS-SEM.

Research hypotheses are as follows:

H1: Professional competencies are positively associated with job proficiency.

H2: Digital transformation is positively associated with job proficiency.

H3: Digital transformation is positively associated with professional competencies.

H4: Digital customs regulations are positively associated with digital transformation.

H5: Digital transformation is positively associated with job proficiency, with professional competencies acting as a mediator.

H6: Digital customs regulations are positively associated with job proficiency through digital transformation.

H7: Digital customs regulations are positively associated with job proficiency through digital transformation and professional competencies.

2. METHODOLOGY

The study followed a quantitative, explanatory–predictive, cross-sectional design. Data were collected in Peru (Lima–Callao) through an online questionnaire administered in October–November 2025 to employees working in customs agencies. This period was selected because digital work practices in customs agencies were already consolidated beyond emergency pandemic responses, allowing respondents to report routine

use of digital procedures and their implications for job proficiency. The Lima–Callao setting is appropriate given the compliance- and traceability-intensive nature of customs intermediation, where regulatory digitization and interoperability requirements are expected to have direct implications for work performance.

Participants were recruited using a non-probabilistic convenience and snowball strategy by disseminating the survey link via WhatsApp. Initial contacts received the link and were invited to forward it to eligible colleagues within customs agencies. This approach was adopted due to the absence of an accessible sampling frame of customs agency employees and the operational constraints typical of regulated work settings, making WhatsApp-based recruitment the most feasible way to reach eligible participants within the study window. Eligibility criteria included: (i) being currently employed in a customs agency, (ii) being involved in customs-related operational or administrative processes, (iii) being 18 years of age or older, and (iv) providing voluntary participation. A total of 104 valid responses were obtained.

The questionnaire used a five-point Likert scale (1 = strongly disagree; 5 = strongly agree) to measure perceptions of digital customs regulations, professional competencies, and job proficiency. Item wording for these constructs was adopted from a previously applied survey scale (Estrada Izquierdo, 2024) and adapted to the customs-agency context. Prior to administration, we reviewed the items to ensure clarity and contextual relevance and retained only those statements directly aligned with the constructs and hypotheses of the proposed model to minimize respondent burden. Digital transformation was operationalized as a higher-order construct represented by score-based indicators (automation and digital channels), consistent with an emergent (formative) specification. For transparency and replicability, the full questionnaire (items, coding, and scoring rules) is provided in Appendix A.

The authors' institution, Peruvian University of Applied Sciences, does not operate a formal research ethics committee for this type of minimal-risk, anonymous survey research. The study therefore followed standard ethical principles, including voluntary participation, informed consent, and confidentiality. Before responding, participants received an information statement describing the study purpose, intended data use, the anonymous nature of responses, and the right to withdraw prior to submission; proceeding to complete the questionnaire was treated as informed consent. No personally identifiable information was collected. Responses were stored in password-protected files accessible only to the research team and were used exclusively for academic purposes.

To address the relationship between digital transformation and job proficiency, structural equation modeling (SEM) was used, as it is a powerful statistical technique used to evaluate complex relationships between observed and latent variables. It is widely applied in various fields, such as business, psychology, sociology, and education, to test theoretical models and hypotheses (Grace, 2022; Khine, 2013; McQuitty & Wolf, 2013; Thakkar, 2020).

ADANCO statistical software version 2.4.1, a specialized application for PLS-SEM, was used. It is designed to facilitate the estimation and evaluation of PLS-SEM models, providing us with tools to analyze complex relationships between latent variables (Memon et al., 2021). It is mainly used as a PLS-SEM estimation environment to contrast theoretical models with complex structures (latent constructs, mediations, moderations, and hierarchical models), especially when the interest combines explanation and predictive capacity. Thus, it has been used to examine phenomena specific to management and organizations, such as the adoption of artificial intelligence in accounting practices (Alruwaili & Mgammal, 2025), the formation of pro-environmental intentions and outcomes in Generation Z through hierarchical models (Shankar et al., 2025), and causal-predictive analysis in service marketing research (Goktas & Dirsehan, 2025).

In ADANCO 2.4.1, the two-stage approach for estimating a higher-order construct in PLS-SEM is executed, operationally, in two consecutive runs. In the first stage, only the measurement model for the first-order constructs (e.g., reflective/formative dimensions) is specified and estimated, along with the structural relationships necessary

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to obtain consistent latent variable scores. After the model converges, the latent variable scores of each dimension are saved for use as inputs in the second run (Cheah et al., 2018; Hair et al., 2019). In the second stage, a new model is constructed in which the higher-order construct is represented using the scores of the dimensions obtained in stage 1 as "indicators", typically defining the higher order as emergent/formative (Mode B) when the dimensions "form" the construct. Then the PLS-SEM model is re-estimated, and the relevant higher-order results are reported (mainly weights and their significance by bootstrap, collinearity/VIF between dimensions, and structural impacts), avoiding reflective metrics (ρA/ρc/AVE) if the higher order is formative (Benitez et al., 2020; Diamantopoulos & Winklhofer, 2001; Jarvis et al., 2003).

The demographic characteristics of the employees who responded to the questionnaire are presented in Table 1. The participation of a greater number of men (65%) stands out. In addition, the representative ages are made up of participants between 26 and 45 years old (a combined total of 79%). Finally, the largest group is made up of employees with between 6 and 14 years of experience in customs work.

Table 1. Demographic profile

Category		Number	Percentage
Gender	Female	36	35%
	Male	68	65%
Age	< 25	2	2%
	26 – 35	44	42%
	36 – 45	38	37%
	46– 55	15	14%
	> 55	5	5%
Years of experience	< 5	22	21%
	6 – 14	51	49%
	15 – 25	24	23%
	> 25	7	7%

Note: N = 104.

3. RESULTS

3.1. Evaluation of the measurement model

The factor loadings of the reflective indicators were high and, in general, above the recommended threshold of 0.70. Job proficiency had loadings ranging from 0.754 (job2) to 0.909 (job3), Professional competencies from 0.818 (profe1) to 0.927 (profe3), and digital customs regulations from 0.777 (dcr2) to 0.927 (dcr3).

For the emerging construct of digital transformation, score-based indicators showed significant loadings (0.369 for Automation_score and 0.697 for Channels_score), consistent with their role as components of the overall operational construct. The reflective specification (Mode A consistent) was retained for professional competencies and job proficiency, and the emergent specification (Mode B) for digital transformation, aligning the measurement with the conceptual nature of each construct.

Likewise, internal consistency was adequate in the reflective constructs, as well as for convergent validity, with scores above 0.50. No ρA/ρc/AVE were reported for digital transformation, given that it is an emerging construct (Mode B) and its evaluation focuses on weights, collinearity, and significance.

Discriminant validity was examined using HTMT, adopting the criterion HTMT < 0.90. The results were: HTMT(PRO–JOB) = 0.870; HTMT(DCR–JOB) = 0.758; HTMT(DCR–PRO) = 0.679.

Additionally, the Fornell–Larcker criterion (presented as correlations squared with AVE on the diagonal) showed high relationships between some constructs; the complete values are shown in Table 3.

HTMT was prioritized as the main evidence of discrimination, in accordance with the explicit threshold decision of 0.90, interpreting the proximity between professional competencies and job proficiency as consistent with their theoretical relationship, without invalidating the empirical differentiation under the adopted criterion.

The collinearity of indicators was acceptable. The VIFs remained below 5: in job proficiency, the highest was 2.883 (job3), in competencies, 3.634 (profe2), and in regulations, 2.652 (dcr3). For the emerging construct of digital transformation, the VIFs of its two indicators (scores) were 2.195, suggesting no problematic collinearity in the formation of the construct, as indicated in Table 4.

Table 2. Factor loading, reliability, and convergent validity

Indicator	Factor Loading	AVE	CR	ρA	ρc	Mean
Digital Customs Regulations (DCR)						
dcr1	0.817					3.95
dcr2	0.777	0.711	0.879	0.8866	0.8800	3.48
dcr3	0.927					3.93
Job Proficiency (JOB)						
job1	0.825					4.03
job2	0.754	0.691	0.867	0.8764	0.8698	3.81
job3	0.909					4.11
Professional Competencies (PRO)						
profe1	0.840					4.14
profe2	0.871	0.760	0.905	0.9058	0.9048	4.17
profe3	0.903					4.07
Digital Transformation (DT)						
Automation_score	0.369					
Channels_score	0.697					

Table 3. Discriminant validity

Construct	JOB	PRO	DT	DCR
Fornell-Larcker Criterion				
JOB	0.691			
PRO	0.755	0.760		
DT	0.753	0.728		
DCR	0.576	0.464	0.760	0.711
HTMT				
JOB				
PRO	0.870			
DCR	0.758	0.679		

Table 4. VIF indicators

Indicator	JOB	PRO	DT	DCR
dcr1				2.373
dcr2				2.295
dcr3				2.652
job1	2.427			
job2	1.967			
job3	2.883			
profe1		2.700		
profe2		3.634		
profe3		2.840		
Automation_score			2.195	
Channels_score			2.195	

It should be noted that regarding the emerging construct of digital transformation (Mode B), the formative weights were statistically significant for both indicators: Automation_score ($w = 0.369$; 95% CI [0.235, 0.515]; $p < 0.001$) and Channels_score ($w = 0.697$; 95% CI [0.553, 0.813]; $p < 0.001$). Likewise, collinearity was acceptable (VIF Automation_score = 2.195; VIF Channels_score = 2.195), which supports the relative contribution of both components without evidence of problematic multicollinearity.

3.2. Structural model evaluation

The model showed high explanatory power: $R^2 = 0.761$ for digital transformation, 0.725 for professional competencies, and 0.814 for job proficiency. As for the direct effects (Table 5 and Figure 1):

- DCR → DT: $\beta = 0.872$, $p < 0.001$; 95% CI [0.789, 0.947].

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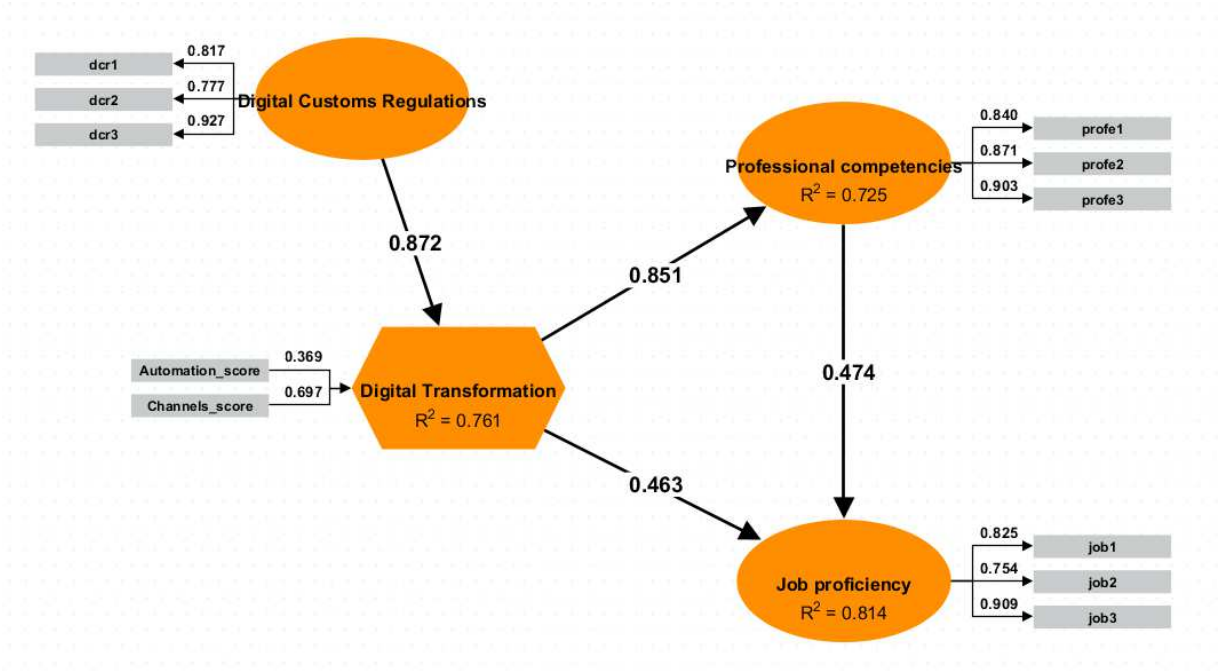

Figure 1. Structural model result

Table 5. Hypotheses testing results – Direct effects

Effect	Original coefficient	Percentile bootstrap quantiles				Supported?
		Mean value	Standard error	t-value	p-value (2-sided)	
PRO → JOB	0.474	0.494	0.208	2.273	0.023	Yes
DT → JOB	0.463	0.445	0.208	2.228	0.026	Yes
DT → PRO	0.851	0.848	0.056	15.313	0.000	Yes
DCR → DT	0.872	0.874	0.041	21.453	0.000	Yes

- DT → PRO: β = 0.851, $p < 0.001$; 95% CI [0.719, 0.934].
- PRO → JOB: β = 0.474, $p = 0.023$; 95% CI [0.137, 0.939].
- DT → JOB: β = 0.463, $p = 0.026$; 95% CI was [–0.009, 0.805], indicating a positive effect with statistical evidence close to the threshold under this type of interval.

Normativity (DCR) was maintained as an antecedent (DCR → DT) and DT as an emergent construct, consistent with the theoretical approach of normativity as an institutional enabler.

Professional competencies were observed to mediate the relationship between digital transformation and job proficiency. The indirect effect was significant: DT → JOB (through PRO): β_ind = 0.403, $p = 0.034$; 95% CI [0.111, 0.844].

Likewise, the influence of DCR on JOB was mainly indirect (through DT and PRO): DCR → JOB (total indirect): β = 0.757, $p < 0.001$; 95% CI [0.606, 0.880]. Based on the total effect of DT on JOB (β_total = 0.866), the mediated proportion (VAF) is approximately 46.5%, which is consistent with a pattern of partial mediation (Table 6).

The effect sizes (Table 7) indicated substantial impacts:

- Digital Transformation → Professional Competencies: $f^2 = 2.680$ (very large).
- Regulations → Digital Transformation: $f^2 = 3.173$ (very large).
- Professional Competencies → Job Proficiency: $f^2 = 0.325$ (medium–large).
- Digital Transformation → Job Proficiency: $f^2 = 0.314$ (medium–large).

Table 6. Hypothesis result – Indirect effects

Effect	Original coefficient	Standard bootstrap results				Supported?
		Mean value	Standard error	t-value	p-value (2-sided)	
DT → JOB	0.403	0.422	0.190	2.120	0.034	Yes
DCR → JOB	0.757	0.759	0.070	10.884	0.000	Yes
DCR → PRO	0.744	0.743	0.071	10.461	0.000	Yes

Table 7. Effect sizes

Effect	Beta	Indirect effects	Total effect	Cohen's f^2
PRO→ JOB	0.473		0.473	0.325
DT → JOB	0.464	0.403	0.867	0.314
DT → PRO	0.853		0.853	2.680
DCR → JOB		0.757	0.757	
DCR → PRO		0.744	0.744	
DCR → DT	0.872		0.872	3.173

Table 8. Overall model adjustment

Model fit index	Goodness of model fit (estimate)			Goodness of model fit (saturate)		
	Value	HI95	HI99	Value	HI95	HI99
SRMR	0.0410	0.0550	0.0648	0.0373	0.0460	0.0542
d_{ULS}	0.1112	0.1999	0.2772	0.0918	0.1398	0.1940
d_G	0.1265	0.2350	0.2973	0.1178	0.2233	0.2854

These results reinforce that the central mechanism of the model is articulated from normativity (antecedent) to digital transformation, and from this to the development of competencies, which in turn increases job proficiency, with an additional direct effect of transformation on proficiency.

3.3. Overall model adjustment

The global fit indices (Table 8) showed an adequate fit for both the saturated and estimated models. Estimated model: SRMR = 0.0410, dULS = 0.1112, dG = 0.1265, all below their quantiles HI95/HI99. Saturated model: SRMR = 0.0373, dULS = 0.0918, dG = 0.1178. Taken together, these results support the adequacy of the model for continuing with the interpretation of the structural component.

4. DISCUSSION

The findings of the estimated model with a two-stage approach suggest that, in the context of customs agencies, digital customs regulation (DCR) operates as a primary determinant of digital transformation (DT), and that the latter translates into substantial improvements in job proficiency (JOB), both directly and through the strengthening of professional competencies (PRO). Taken together, the pattern of empirical relationships forms a consistent argument: institutionally regulated public organizations do not depend solely on "technology adoption," but on an institutional and organizational architecture that enables capabilities and, ultimately, performance.

First, the effect DCR → DT is high and statistically significant ($\beta = 0.872$; $p < 0.001$), with a very large effect size ($f^2 = 3.173$). This result positions regulation as a factor that not only "pushes" for digitization but also structures the scope and direction of change. In the public sphere, digital transformation is often deployed as a process of redesigning services, rules, and practices under expectations of traceability, control, and transparency; therefore, the role of regulatory frameworks and formal mandates tends to be particularly central (Mergel et al., 2019). In interpretive terms, the magnitude of the effect suggests that, in environments such as customs, digital transformation becomes less of a discretionary initiative and more of a compliance and standardization mechanism, aligned with the logic of "transformation" as a profound reconfiguration of processes and governance (Vial, 2019).

Secondly, there is a strong direct effect of DT → PRO ($\beta = 0.851$; $p < 0.001$), with $f^2 = 2.680$, which

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indicates that digital transformation is strongly associated with the strengthening of competencies. This relationship is consistent with the idea that digitization, when consolidated into work processes and channels, systematically exposes civil servants to new routines, data languages, and interaction standards, generating organizational learning and skill development. From the perspective of dynamic capabilities, digital transformation can be understood as a process of strategic renewal and continuous reconfiguration of resources, in which competence (individual and collective) is an expected outcome and, at the same time, an input for sustaining change (Teece et al., 1997; Warner & Wäger, 2019).

Thirdly, professional competencies have a positive and significant effect on job proficiency (PRO → JOB: β = 0.474; p = 0.023; f^2 = 0.325). In substantive terms, this indicates that performance (or quality/effectiveness of work) increases as staff develop competencies to interact with digital tools, data, and routines. This result converges with previous evidence linking digital competencies to performance, including models where the effect is explained by psychological or organizational mechanisms (e.g., empowerment, autonomy, or perceived efficacy), maintaining a significant contribution to performance in work tasks (Ochoa Pacheco & Coello-Montecel, 2023). Furthermore, it is worth remembering that digital competencies are often linked to broader competencies (critical thinking, problem solving, communication), so strengthening them can have an impact on both routine tasks and professional judgment in highly controlled contexts, such as customs (van Laar et al., 2017).

A particularly relevant finding is that digital transformation also has a direct effect on job proficiency (DT → JOB: β = 0.463; p = 0.026; f^2 = 0.314). This suggests that, even before considering the competencies component, digital transformation introduces performance gains associated with operational efficiency, friction reduction, standardization, and traceability. In terms of resource theory, this can be interpreted as an increase in labor productivity through the mere reconfiguration of processes and complementary assets (Barney, 1991). Consistent with studies in other sectors, digitization can improve organizational results by enhancing controls, information quality, and governance mechanisms. For example, digital transformation has been shown to contribute to performance through improvements in the quality of internal control, which is conceptually close to the logic of traceability and control in regulated environments (Zhang & Dong, 2023).

However, the mediation analysis reinforces the interpretation of a dual mechanism: DT increases job proficiency (i) through a direct effect and (ii) through competencies. The indirect effect DT → PRO → JOB is significant (β_ind = 0.403; p = 0.034). This implies that almost half of the impact of digital transformation on performance is channeled through professional competencies, while the rest is explained by direct benefits from digital process redesign. This structure is consistent with approaches that distinguish "operational digitization" from "transformation" as a capability: in different stages, transformation generates returns both through system improvements and through learning and competencies accumulation, although the specific mechanisms may vary depending on the degree of maturity of the change (Tian & Ou, 2024). In practical terms, partial mediation suggests that it is not enough to simply implement platforms: performance improves more robustly when the organization ensures conditions for staff to internalize competencies associated with the new work environment.

Regarding the explanatory power of the model, the reported R^2 values are high for the endogenous variables (DT = 0.761; PRO = 0.725; JOB = 0.814), suggesting that the institutional-capacity framework captured by the model explains a considerable proportion of the variance in transformation, competencies, and proficiency. Additionally, the reported overall fit (e.g., SRMR saturate = 0.0373; SRMR estimate = 0.0410; NFI ≈ 0.919) is consistent with an adequate representation of the data under the estimated approach. This overall performance strengthens the argumentative interpretation: the model not only identifies significant relationships but also configures a plausible explanatory structure for a highly regulated public environment, where digital transformation materializes as a combination of regulatory framework, capacity for change, and human capital competencies.

The implications for public customs management are direct. If digital customs regulation is a central driver of transformation (DCR → DT), then regulatory design must prioritize not only the mandate, but also operability: clear standards, interoperability, data guidelines, and traceability criteria that reduce ambiguity and adoption costs. At the same time, given the partial mediation, the effectiveness of the transformation depends on active policies of continuous training and change management, aimed at converting digitization into competencies applied to the workplace. Comparative evidence in Peruvian contexts suggests that the combination of digital transformation and competencies is associated with organizational improvements when articulated with management practices (e.g., digital human resources or practices oriented toward sustainability and performance), reinforcing the need for comprehensive interventions and not merely technological ones (Espina-Romero et al., 2024).

Finally, it is important to recognize limitations and avenues for further research. Given the type of measurement and scope of the study, it is reasonable to consider typical risks of cross-sectional and self-reported designs (e.g., common method bias), as well as the need to contrast these mechanisms with objective indicators of productivity or service quality. The non-probabilistic WhatsApp-based recruitment may limit statistical generalizability; therefore, results are interpreted as explanatory–predictive evidence for similar customs-agency contexts.

Future research could also explore moderators (digital maturity, leadership, infrastructure, compliance culture) and compare subgroups (e.g., operational vs. analytical areas). In particular, the phased approach suggests that mechanisms may differ depending on the stage of the transformation process; therefore, longitudinal or quasi-experimental designs would allow for a more accurate assessment of the transition from regulation and adoption to competencies and sustained performance.

Based on the above, the results show that digital transformation in customs agencies is strongly driven by the regulatory environment and translates into performance through a dual channel: system efficiency/structure and competencies development. This dual approach provides a clear argument for public policy: digitization is necessary, but turning digitization into proficiency requires systematic investment in capabilities and organizational learning.

CONCLUSION

This study aims to model and empirically test the relationships among digital customs regulations, digital transformation, professional competencies, and job proficiency in Peruvian customs agencies, as well as the mediating role of professional competencies, using PLS-SEM.

The findings provide convergent evidence for a mechanism in which digital customs regulations act as an upstream enabler of digital transformation, and digital transformation enhances job proficiency through two complementary pathways: direct process-related improvements and the strengthening of professional competencies. In other words, regulatory digitization appears to structure the scope and direction of transformation, while competencies translate technological change into sustained work proficiency.

From a practical perspective, the results imply that customs modernization should be implemented as an institutional–capability package. Regulatory reforms should prioritize operational clarity, interoperability requirements, and enforceable digital procedures, while agencies should invest in structured competency development so that employees can effectively appropriate digital tools and redesigned workflows.

These conclusions should be interpreted considering the study's cross-sectional and self-reported nature. Further research would benefit from longitudinal designs, the inclusion of objective performance indicators (e.g., clearance time or error rates), and tests of boundary conditions such as agency size, functional area, and the maturity stage of digitization.

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STATEMENT ON AI USE

The authors declare that no artificial intelligence tools were used for data analysis or interpretation. DeepL was used for translation and language editing. The authors verified the accuracy of the translation, revised the wording as necessary, and assume full responsibility for the manuscript.

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APPENDIX A

Table A1. Questionnaire

Code	Construct	Item (EN)	Item (ES – original)
dcr1	Digital customs regulations	Before the pandemic, I was familiar with the digital regulations applicable to my work within the customs agency.	¿Antes de la pandemia conocía las normativas digitales aplicables en mi trabajo dentro de la agencia de aduana?
dcr2	Digital customs regulations	During the pandemic, I perceived that digital regulations were updated more frequently and became more demanding in the agency.	¿Durante la pandemia percibí que la normativa digital se actualizó con mayor frecuencia y exigencia en la agencia?
dcr3	Digital customs regulations	The digital rules applied during the pandemic were clear and understandable for customs agency staff.	¿Las normas digitales aplicadas en la pandemia fueron claras y comprensibles para los colaboradores de la agencia de aduana?
auto1	Digital transformation – Automation	Before the pandemic, automated processes coexisted with manual tasks in the agency.	¿Antes de la pandemia coexistían los procesos automatizados con tareas manuales en la agencia?
auto2	Digital transformation – Automation	During the pandemic, digital automation significantly reduced my manual workload.	¿Durante la pandemia la automatización digital redujo significativamente la carga de tareas manuales en mi trabajo?
auto3	Digital transformation – Automation	The automated systems implemented during that period operated quickly and continuously in the customs agency.	¿Los sistemas automatizados implementados en ese periodo funcionaron con rapidez y continuidad en la agencia de aduana?
chan1	Digital transformation – Digital channels	Before the pandemic, the use of digital channels in the customs agency was limited compared with in-person procedures.	¿Antes de la pandemia el uso de canales digitales en la agencia de aduana era limitado frente a los trámites presenciales?
chan2	Digital transformation – Digital channels	During the pandemic, digital channels (e.g., VUCE and internal platforms) made work in my area (operational or administrative) more agile.	¿Durante la pandemia los canales digitales (como la VUCE y plataformas internas) agilizaron el trabajo en mi área (operativa o administrativa)?
chan3	Digital transformation – Digital channels	Digital channels created or strengthened during the pandemic allowed greater control and tracking of the agency's processes.	¿Los canales digitales creados o reforzados en la pandemia me permitieron tener mayor control y seguimiento de los procesos de la agencia?
job1	Job proficiency	During the pandemic, I maintained the quality of the functions I performed within the customs agency.	¿Durante la pandemia mantuve la calidad en las funciones que desempeñaba dentro de la agencia de aduana?
job2	Job proficiency	My performance in the agency was characterized by precision and reliability in that context.	¿Mi desempeño en la agencia se caracterizó por la precisión y confiabilidad en ese contexto?
job3	Job proficiency	Pandemic-driven digitization enabled me to effectively resolve procedures or responsibilities assigned in my work area.	¿La digitalización forzada por la pandemia me permitió resolver con eficacia las gestiones o responsabilidades asignadas en mi área de trabajo?
profe1	Professional competencies – Adaptability	During the pandemic, I quickly adapted to new digital and organizational procedures in the agency.	¿Durante la pandemia me adapté rápidamente a los nuevos procedimientos digitales y organizacionales en la agencia?
profe2	Professional competencies – Adaptability	I managed to maintain good performance despite changes in the work modality (remote or hybrid).	¿Logré mantener un buen desempeño a pesar de los cambios en la modalidad de trabajo (remoto o mixto)?
profe3	Professional competencies – Adaptability	I developed competencies (technological and operational) that strengthened my responsiveness within the agency.	¿Desarrollé competencias (tecnológicas y operativas) que fortalecieron mi capacidad de respuesta en la agencia?

Note: For the PLS-SEM analysis, Digital Transformation (DT) was specified as a higher-order emergent (formative; Mode B) construct and operationalized through two score-based indicators: Automation_score and Channels_score, computed as the arithmetic mean of items auto–auto3 and chan1–chan3, respectively.