Designing an ICT-Based Digital Transformation Roadmap for Administrative Process Optimization in a Municipal Public Utility

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Article

Designing an ICT-Based Digital Transformation Roadmap for Administrative Process Optimization in a Municipal Public Utility

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Abstract

Digital transformation in public institutions is increasingly understood as a socio-technical and organizational process rather than a purely technological upgrade. This study presents the design of an ICT-based digital transformation roadmap aimed at improving administrative efficiency and citizen service delivery in a municipal public utility in Ecuador. A mixed-methods diagnostic approach was adopted, combining qualitative evidence from direct observation and a semi-structured interview with the head of the IT department, and quantitative data from a structured online survey administered to citizens. Baseline Key Performance Indicators (KPIs) were established using institutional records, service logs, and workflow analysis conducted over a three-month diagnostic window. Post-implementation KPI values are explicitly treated as ex ante projections, derived from process redesign analysis, benchmarking with comparable public utilities, and scenario-based assumptions, rather than empirically observed outcomes. The empirical results demonstrate high citizen readiness and acceptance of proposed digital services, including remote service portals, electronic invoicing, and automated support channels. The projected operational improvements—such as reductions in response and administrative processing times and increased digital transaction rates—are therefore presented as expected performance scenarios. A risk and alternative scenario analysis further examines how organizational constraints, resource availability, governance capacity, and change-management factors may moderate these outcomes. The study contributes a transparent and replicable framework for diagnosing digital readiness and planning ICT-driven transformation initiatives in resource-constrained public utilities, while emphasizing the need for future longitudinal validation using post-implementation data.

Keywords: digital transformation; customer relationship management (CRM); administrative process optimization; public utilities; e-government

1. Introduction

Digital transformation in the public sector has emerged as a strategic axis for improving administrative efficiency, institutional transparency, and the quality of citizen services. In this context, Information and Communication Technologies (ICTs) play a pivotal role by enabling process automation, data-driven decision-making, and more agile interactions between institutions and users. However, digital transformation extends far beyond the mere deployment of technological tools. It entails profound changes in operational processes, organizational structures, functional roles, training models, institutional culture, digital governance, and interdepartmental coordination [1]. Following Saeedikiya et al. [2], digital transformation can be understood as the reconfiguration of processes, technologies, and human capabilities to generate sustained organizational value. In municipal public

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utilities, such value is reflected not in profit maximization but in improved service reliability, faster response times, reduced cost-to-serve, enhanced transparency, and increased citizen trust.

The literature consistently emphasizes that the success of digital transformation in public institutions depends not only on technological infrastructure but also on human, organizational, and institutional factors. Empirical studies have shown, for example, that the adoption of AI-based chatbots in Korean government agencies is strongly conditioned by employee trust and organizational support [3]. Likewise, the emotional intelligence and digital readiness of public servants have been identified as key determinants of effective AI deployment in public administration [4]. These findings reinforce the view that digital transformation is a socio-technical process in which governance, skills, and change management play a decisive role.

Public utilities in Latin America—particularly those responsible for essential services such as water supply and sanitation—face increasing pressure to modernize administrative processes and improve service delivery. Despite this pressure, many of these organizations continue to operate with limited technological infrastructure, fragmented workflows, and heterogeneous levels of digital literacy among staff [5]. Evidence from Ecuador illustrates these challenges clearly. A recent case study conducted in Guayaquil identified significant gaps in technological infrastructure, personnel training, and regulatory frameworks for the ethical and effective adoption of emerging digital technologies [6]. Similar patterns have been reported across the region, where successful digital initiatives are associated with adaptive governance models, competency-based capacity building, and institutional coordination rather than technology alone [7,8].

Against this background, the present study focuses on a municipal public utility in Ecuador providing basic public services, where administrative performance has been constrained by manual procedures, limited automation, and weak interdepartmental integration. Rather than evaluating an already implemented digital transformation, this research adopts a diagnostic and design-oriented approach. Specifically, it combines an organizational ICT diagnostic—based on interviews, institutional records, and direct observation—with a citizen perception survey to identify critical bottlenecks, readiness conditions, and social acceptance of proposed digital services. On this basis, the study develops an ICT-based improvement roadmap aimed at modernizing administrative and operational management through process redesign, capacity building, and modular technology adoption.

From a scientific standpoint, this study contributes to the digital government and public management literature by providing empirical evidence from a developing-country context through two complementary components: (i) a structured diagnostic assessment of administrative processes and ICT readiness, and (ii) an analysis of citizen attitudes toward proposed digital service channels. Building on this evidence, the paper designs a modular ICT roadmap—including CRM systems, Virtual Offices, mobile applications, and electronic invoicing—and reports *ex ante* performance scenarios expressed through Key Performance Indicators (KPIs). These KPI values represent projections derived from baseline measurements, process redesign analysis, and benchmarking with peer utilities, rather than post-implementation empirical outcomes.

Importantly, this framing distinguishes clearly between observed conditions and anticipated effects. The study does not claim to measure the realized impact of digital transformation; instead, it provides a needs assessment and a structured intervention proposal supported by diagnostic data and citizen perceptions. As such, the contribution lies in clarifying what improvements are plausible under specific organizational and technological assumptions, while explicitly acknowledging the uncertainties and constraints associated with implementation.

The remainder of this article is organized as follows. Section 2 reviews the main theoretical and empirical contributions related to ICT-driven administrative modernization in public institutions, with particular emphasis on developing-country and Latin American contexts. Section 3 describes the methodological design, including data collection techniques, population and sampling, instrument validation, and KPI definition. Section 4 presents the diagnostic findings, the proposed ICT-based solutions, and the projected performance scenarios derived from process redesign analysis and bench-

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marking assumptions. Section 5 discusses these findings in light of regional experiences and existing literature, highlighting implications for governance, organizational change, and digital readiness. Finally, Section 6 summarizes the main contributions, limitations, and recommendations for future empirical evaluation of digital transformation initiatives in municipal public utilities.

2. Literature Review

Digital transformation in public administration, particularly in developing countries, has become a key driver of institutional modernization, transparency, and service efficiency. Recent studies emphasize that effective adoption of ICTs in the public sector requires not only technological investment but also organizational readiness, regulatory alignment, and contextual adaptation [9,10]. In Latin America, public institutions continue to face challenges related to digital inequality, infrastructural gaps, and fragmented policy implementation, which hinder uniform progress in e-government initiatives [11,12].

Despite growing research on digital transformation in public and private sectors, the literature still lacks a systematic integration of key theoretical frameworks such as the Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and Digital Maturity Models—especially in studies applied to developing countries. Some recent works have begun to address this gap. For instance, Saeed et al. [13] employ the UTAUT3 model to analyze the adoption of CRM-driven service robots in Iraqi restaurants, finding that behavioral intention is shaped not only by classical UTAUT factors (e.g., performance expectancy, effort expectancy), but also by individual innovativeness and hedonic motivation—emphasizing the need to contextualize technology acceptance frameworks in emerging economies with limited digital maturity. Similarly, Juita et al. [14] extend the Technology-Organization-Environment (TOE) framework by incorporating self-efficacy and trust as mediating and moderating variables in digital market adoption among underserved MSMEs, thus reflecting the psychological and structural barriers faced by small organizations in developing regions. These studies suggest that theoretical models like UTAUT and TAM remain highly relevant for explaining digital adoption, but require contextual calibration to address infrastructural, cultural, and institutional constraints. Furthermore, while maturity models are frequently used to guide digital progress in developed nations, Carlsson et al. [15] argue that inter-municipal collaboration can act as a compensatory mechanism to advance digital capabilities in municipalities with resource disparities, providing an alternative pathway to digital maturity that is more collaborative than hierarchical. Despite these contributions, a broader integration of these frameworks in municipal and public utility contexts remains limited, signaling an important direction for future research and practice.

The transformation of municipal and local government services through digital tools has been documented in a range of contexts, offering insights into both barriers and enablers. For instance, the case of Tabriz municipality in Iran illustrates how IoT technologies can enhance urban service delivery when integrated within a supportive policy and infrastructural environment [9]. In Mozambique, small enterprises adopting digital tools face cybersecurity challenges due to lack of awareness and tailored frameworks, highlighting the need for contextual cybersecurity governance in developing nations [16]. Carlsson et al. [15] examine inter-municipal cooperation in Sweden as a strategy for overcoming local resource disparities, a model that could inform digital transformation efforts in under-resourced Latin American municipalities.

Other studies emphasize the importance of user trust, inclusion, and participation in the success of digital government initiatives. Nyadzi and Morris [12] find that e-government can enhance public trust if accompanied by consistent service performance and contextual responsiveness. At the same time, bridging the digital divide remains a persistent challenge. Sagala and Őri [11] propose alternative strategies for inclusive e-government in developing countries, including multi-channel service provision and user mobilization initiatives.

Digital transformation also intersects with broader governance and sustainability goals. In the domain of higher education, Twabu and Nakene-Mginqi [17] explore how blockchain-enabled smart contracts can streamline data access and verification across public institutions. In environmental gov-

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ernance, Xiong and Yu [18] demonstrate a nonlinear relationship between e-government development and carbon emission efficiency across 136 countries, suggesting that digital maturity is critical for maximizing policy impacts.

While much progress has been made in theorizing and documenting digital transformation, the literature still calls for more grounded, municipal-level case studies that integrate technological, organizational, and citizen-centered dimensions. Existing frameworks and international experiences provide a foundation, but their application to Latin American public utilities—especially in Ecuador—remains limited. This study addresses that gap by offering an empirical examination of digital transformation within a municipal public service in Ecuador, contributing new insights to both regional scholarship and global theoretical debates.

3. Materials and Methods

3.1. Research Design

The research adopted a mixed-methods design that integrated descriptive, diagnostic, explanatory, and evaluative approaches to analyze the administrative processes of a municipal public utility in Ecuador and the role of Information and Communication Technologies (ICTs) in improving efficiency and service quality. The descriptive component focused on characterizing the technological infrastructure, information systems, and administrative workflows; the diagnostic phase identified critical areas of improvement and current limitations; the explanatory analysis examined how ICT implementation could influence process optimization; and the evaluative dimension assessed potential gains in efficiency and citizen satisfaction.

The methodological structure combined both qualitative and quantitative strategies. Qualitative techniques, such as direct observation and semi-structured interviews with the head of the Information Technology Department, allowed for a contextual understanding of digital practices, technological gaps, and user interactions with administrative systems. Quantitative methods were applied through structured surveys administered to service users, providing measurable insights into satisfaction levels, perceptions of efficiency, and acceptance of proposed digital tools.

This cross-sectional design enabled the collection and analysis of data within a specific timeframe, establishing a baseline for subsequent performance assessment using Key Performance Indicators (KPIs). The design ensured a comprehensive evaluation of the institution's digital maturity and readiness for administrative modernization through ICT integration, aligning methodological rigor with the study's applied orientation toward organizational improvement.

3.2. Data Collection Techniques

The data collection process combined qualitative and quantitative techniques aligned with the study's diagnostic and evaluative approach. Three primary instruments were used: direct observation, semi-structured interviews, and structured surveys.

The observation technique was applied to analyze the technological infrastructure and administrative workflows within the organization, identifying existing digital tools, areas of inefficiency, and opportunities for automation. This allowed a first-hand understanding of how administrative activities were managed and how technology was integrated into daily operations.

Semi-structured interviews were conducted with the head of the Information Technology Department to obtain detailed insights into the institution's technological capabilities, system functionality, and current limitations in ICT adoption. The interview guide consisted of 12 open-ended questions focusing on digital resource management, data systems, and human capital competencies.

A structured survey composed of 13 multiple-choice questions was administered to service users to assess their satisfaction and perception of digital service quality. The survey was distributed electronically using Google Forms, enabling efficient data collection and ensuring accessibility for participants. The questionnaire addressed topics such as service responsiveness, ease of use of digital tools, and perceived improvements in transparency and administrative efficiency. Descriptive and

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inferential statistical analyses were conducted to provide a robust assessment of satisfaction levels. Survey participants were recruited from the institutional customer database through online invitations, yielding a convenience sample; therefore, potential self-selection and digital-access bias associated with online-only data collection is acknowledged as a limitation.

Together, these techniques provided a multi-perspective understanding of the organization's readiness for digital transformation, combining empirical evidence from internal stakeholders and end users.

3.3. Population and Sampling

The study population consisted of 31,147 active users registered in the customer database of the municipal public utility. From this total, a representative sample of 380 individuals was determined using the finite population formula, which corrects the estimation when the population is not large enough to assume infinite conditions [19]. Applying a 95% confidence level, a 5% margin of error, and assuming maximum variability ($P = Q = 0.5$).

$$n = \frac{Z^2 \times P \times Q \times N}{E^2(N-1) + Z^2 \times P \times Q} \tag{1}$$

where n is the sample size, N is the population size, $Z = 1.96$ corresponds to a 95% confidence level, $E = 0.05$ is the acceptable margin of error, and P and Q represent the probability of success and failure, respectively. Substituting these values produced a sample size of $n = 380$ participants.

This sampling approach ensured statistical representativeness of the population and reliability in estimating users' perceptions and behaviors. The selection process employed a simple random sampling method, allowing equal opportunity for all active customers to be included in the survey. The resulting dataset served as a foundation for evaluating service satisfaction, efficiency indicators, and the overall acceptance of ICT-based administrative modernization.

3.4. Instrument and Construct Definition

The data collection instrument consisted of a structured questionnaire composed of 13 closed-ended items, administered through Google Forms. All attitudinal questions were measured using five-point Likert-type scales, adapted to the nature of each item (e.g., agreement, perceived importance, or likelihood of use). The questionnaire was designed to capture citizens' perceptions regarding the proposed digital transformation initiatives at the municipal institution.

Based on a conceptual review of digital transformation, e-government, and public service modernization literature, the items were grouped into nine analytical constructs. Four constructs were operationalized as multi-item scales: *ICT Infrastructure Improvement* (Items Q1–Q2), *Process Automation Perception* (Items Q3–Q4), *Digital Self-Service Adoption* (Items Q5–Q6), and *Chatbot Acceptance* (Items Q7–Q8). The remaining items (Q9–Q13) were treated as single-indicator constructs, addressing specific dimensions such as document digitalization, electronic invoicing preference, mobile meter-reading applications, staff training, and the use of Geographic Information Systems (GIS).

The internal consistency of the multi-item constructs was assessed using Cronbach's alpha coefficient. Reliability analysis was conducted using the R statistical environment, employing the `psych` package. Table 1 presents the obtained reliability coefficients.

Table 1. Internal consistency of multi-item constructs.

Construct	Items	Cronbach's α
ICT Infrastructure Improvement	Q1–Q2	0.78
Process Automation Perception	Q3–Q4	0.81
Digital Self-Service Adoption	Q5–Q6	0.84
Chatbot Acceptance	Q7–Q8	0.79

All Cronbach's alpha values exceeded the recommended threshold of 0.70, indicating acceptable internal consistency and supporting the reliability of the measurement instrument.

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3.4.1. Content Validity

Content validity was ensured through a systematic review of prior studies on digital transformation, e-government services, and ICT adoption in public utilities. The questionnaire items were formulated to reflect key dimensions identified in the literature, such as service efficiency, accessibility, transparency, and technological acceptance. Additionally, the instrument was reviewed by domain experts in public administration and information systems, who assessed the clarity, relevance, and coherence of the items. Minor wording adjustments were made to improve comprehension, ensuring that the instrument adequately represented the constructs under study.

3.5. Application of Key Performance Indicators (KPIs)

To evaluate the operational improvements derived from the implementation of Information and Communication Technologies (ICTs), a set of Key Performance Indicators (KPIs) was defined. These indicators were selected based on the main challenges identified in the diagnostic phase and aligned with the strategic objectives of the digital transformation proposal. The KPIs aim to quantify efficiency gains, reductions in administrative delays, process automation rates, and improvements in citizen satisfaction.

Table 2. Key Performance Indicators (KPIs) for evaluating ICT-based process optimization.

KPI Name	Description and Objective	Formula / Measurement Approach
Average Response Time (ART)	Measures the speed with which citizen requests are managed, from receipt to resolution. Indicates the efficiency of service workflows and the impact of automation on turnaround time.	$ART = \frac{\sum_{i=1}^{n}(t_{closure_i} - t_{req_i})}{n}$ where $t_{closure}$ = resolution timestamp, t_{req} = submission timestamp, and n = total number of requests.
Administrative Processing Time (APT)	Evaluates the reduction in time required to complete administrative procedures through the digitalization of documents and automation of internal approvals.	$APT = \frac{T_{before} - T_{after}}{T_{before}} \times 100\%$ where T_{before} and T_{after} represent the average processing time before and after ICT implementation.
Digital Transaction Rate (DTR)	Assesses the increase in the number of digital transactions (payments, service requests, online claims) performed by users without in-person assistance. Reflects citizen adoption of digital channels.	$DTR = \frac{N_{digital}}{N_{total}} \times 100\%$ where $N_{digital}$ = transactions completed via digital platforms, and N_{total} = total transactions.
Automated Task Ratio (ATR)	Quantifies the proportion of internal processes automated by ICT tools, reducing manual workload and potential human error.	$ATR = \frac{N_{automated}}{N_{total\_tasks}} \times 100\%$ where $N_{automated}$ = automated processes, and N_{total_tasks} = total administrative tasks identified.
Citizen Satisfaction Index (CSI)	Evaluates the perception and satisfaction level of users regarding the digital services implemented. Based on pre- and post-implementation survey scores.	$CSI = \frac{\overline{S_{after}} - \overline{S_{before}}}{\overline{S_{before}}} \times 100\%$ where $\overline{S}$ = average satisfaction score (Likert 1–5 scale) from user surveys.

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The baseline values of the KPIs were obtained from institutional sources, including semi-structured interviews with the head of the IT department, direct observation of administrative workflows, and analysis of operational practices supported by the existing ERP system. These values represent average pre-digitalization performance. Estimated post-implementation KPI values were derived using an ex ante approach based on process redesign analysis and benchmarking against comparable municipal public utilities, as documented in the associated master's thesis.

The use of KPIs in this study responds to the lack of empirical performance-based evaluations identified in prior research on digital transformation in municipal public utilities.

Each KPI provides a quantitative and comparable measure of progress toward digital transformation goals. The combination of response time, digital usage, and satisfaction indicators ensures a balanced assessment between operational efficiency and citizen-centered outcomes. The metrics are periodically reviewed on a quarterly basis to adjust implementation priorities and to track sustainability of improvements in the long term.

3.5.1. KPI Measurement Methods and Data Sources

To ensure methodological transparency and address the traceability of the reported performance indicators, this subsection describes how each Key Performance Indicator (KPI) was measured and the institutional data sources used to obtain baseline values. The measurements are grounded in empirical evidence collected through interviews, direct observation, administrative records, and user surveys conducted during the diagnostic phase. Table 3 summarizes the measurement approach and data sources associated with each KPI, providing a clear basis for the ex ante performance estimations and supporting future longitudinal validation.

Table 3. KPI measurement methods and data sources.

KPI	Measurement Method	Data Source
Average Response Time (ART)	Mean time between request submission and resolution, calculated from operational timestamps.	Manual service logs, internal administrative records, direct observation, and semi-structured interview with the head of the IT department.
Administrative Processing Time (APT)	Average duration required to complete administrative procedures from submission to closure.	Direct observation of workflows, institutional operational practices, and records supported by the ERP system.
Digital Transaction Rate (DTR)	Ratio of digitally processed transactions to total transactions during the baseline period.	Administrative reports, direct observation of service channels, and analysis of existing digital platforms.
Automated Task Ratio (ATR)	Proportion of administrative tasks fully automated by ICT tools.	Process mapping, system configuration review, and ERP functional analysis.
Citizen Satisfaction Index (CSI)	Mean satisfaction score measured using a five-point Likert scale.	Structured online survey administered to service users.

4. Results

4.1. Baseline Status of Technological Resources Used in Administrative Processes

This subsection summarizes the initial state of information and communication technology (ICT) resources in a municipal public basic-services utility in Ecuador.[1] Evidence comes from (i) a structured

[1] Source: interview with the head of IT services and in-situ observation.

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interview with the head of IT services and (ii) direct observation of information flows and work practices across administrative units.

Hardware and Connectivity.

The organization operates *32 desktop computers*, with an average age close to *seven years*, which constrains performance and the ability to run newer software versions.[2] Internet service quality is reported as *good/stable*, enabling day-to-day operations of administrative systems. Peripherals (laser printers and document scanners) are in *good working condition*; printers are heavily used in the technical and finance areas, while scanners are used on demand by each department.

Business Software Landscape.

The utility uses an ERP platform ("CABILDO") for core administrative processes. Users report *high ease of use* and no currently obsolete software modules; nonetheless, forward compatibility and upgrade paths should be continuously reviewed.

Process Automation Coverage.

Several back-office processes are fully automated: *revenue collection*, *human resources*, *stock and inventory*, *customer database*, and *accounting*. Two critical customer-facing domains remain largely manual: *customer service* and the *technical department* (e.g., leak reporting, service lead-in installation, meter installation, and sewer collapse reports).

Human Capabilities and Change Readiness.

Staff ICT proficiency is assessed as *intermediate*. Identified skill gaps are not being addressed by systematic training programs at present, which creates a risk for future digital initiatives. Attitudes toward new technologies are *generally positive*, with pockets of resistance largely attributable to limited training and change-management support.

Table 4. Interview highlights with the head of IT services (synthesis).

Topic	Key finding
End-user devices	32 desktops; age ∼7 years; performance constraints expected for new apps.
Connectivity	Internet service rated as good/stable for core operations.
Peripherals	Printers heavily used; scanners used as needed; overall good condition.
ERP in use	ERP "CABILDO" in production; ease of use reported; monitor upgrade paths.
Automation coverage	Automated: collection, HR, inventory, customer DB, accounting. Gaps: customer service & technical ops.
Skills & training	Staff proficiency: intermediate; no active upskilling program despite identified gaps.
Adoption attitude	Generally positive; localized resistance tied to training deficits.

Compact SWOT at Baseline.

The baseline diagnostic of the municipal public basic-services utility reveals a mixed technological landscape in which a functional institutional website, stable connectivity, and an operational ERP coexist with pockets of manual work, fragmented data, and aging end-user hardware. Staff show intermediate ICT proficiency and generally positive attitudes toward change, though the lack of structured training and limited cybersecurity practices constrain readiness for deeper digitalization. At

[2] Device count and obsolescence risk.

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the same time, there are clear external and internal levers for improvement—particularly the adoption of CRM/workflow platforms, virtual office and mobile channels, and GIS/AI-enabled analytics, alongside potential funding programs. These findings are synthesized in the SWOT matrix of Table 5, which distills the strengths and opportunities to be leveraged, as well as the weaknesses and threats to be managed during the transformation roadmap.

Table 5. Baseline SWOT of technological management in administrative processes (diagnostic at Section 4.1).

STRENGTHS	OPPORTUNITIES
• Working website and basic digital channels for citizen communication. • Availability of baseline ICT infrastructure (printers/scanners; stable internet). • Core administrative systems (ERP) operating with acceptable usability. • Institutional interest and commitment to modernization initiatives.	• Access to modern management tools (CRM/service desk, workflow engines, dashboards). • External funding windows and national/local programs supporting digitalization. • Benchmarking from peer public utilities to accelerate best-practice adoption. • Adoption of emerging technologies (cloud, GIS, IoT, AI, big data analytics) to enhance decision-making and service quality. • Expansion of 24/7 digital channels (Virtual Office and mobile apps) to improve user experience.
WEAKNESSES	**THREATS**
• Partial digitization: persistence of manual workflows in customer service and technical operations. • Data fragmentation and limited integration between areas/systems. • Outdated end-user hardware; heterogeneous software stack. • Limited cybersecurity posture (policies, tools, and monitoring). • Intermediate ICT proficiency; absence of a structured training program; pockets of resistance to change.	• Cybersecurity risks (malware, data breaches) and service continuity issues. • Budgetary pressure for upgrades; cost overruns during transition. • Dependency on legacy systems and vendor lock-in. • Regulatory and compliance changes (data protection, fiscal e-invoicing) increasing complexity. • User resistance and adoption risks that may delay benefits realization.

4.2. Integrated ICT Proposal to Optimize Administrative and Operational Management

Grounded on the baseline diagnostic and the comparative review of solutions adopted by peer utilities in Ecuador, we propose a staged ICT roadmap focused on closing the most critical bottlenecks in customer service and technical operations while reinforcing back-office reliability and governance . Each block states the problem, the solution, implementation details, and an indicative timeline.

Infrastructure Refresh (3–6 months).

Problem: Seven-year-old desktops and heterogeneous peripherals constrain performance and hinder the adoption of new cloud/SaaS tools .
Solution: Refresh end-user devices (mid-range desktops/laptops), consolidate multifunction printers and high-speed scanners, and standardize the OS/software image .
Implementation details: Minimum hardware baseline (e.g., quad-core CPU, 8–16 GB RAM, SSD), inventory and imaging with centralized management; replace end-of-life printers; service-level war-

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ranties; basic endpoint protection .
Indicative timeline: 3–6 months, executed in two waves (critical areas first) .

Case and CRM System for Citizen Service Requests (6–12 months).

In this context, the CRM functions as a unified case management system that handles both technical service requests (e.g., leaks, meter installation) and administrative procedures, ensuring end-to-end traceability and citizen-centered service delivery.

Problem: Manual intake and tracking of technical requests (leaks, meter installation, sewer incidents) cause delays, rework, and poor visibility

Solution: Deploy a cloud-based service desk/CRM adapted to public utilities to register, triage, dispatch, and monitor requests end-to-end (e.g., a Freshdesk-class platform) [20].

Implementation details: Multichannel intake (web portal, email, phone logging); automatic assignment by location/priority/specialty; SLAs and escalations; notifications to users/technicians; dashboards and KPI reports (time-to-respond, time-to-resolve, SLA compliance); integration with the ERP for customer/master data and billing events [20].

Figure 1. Freshdesk multichannel interaction model. Source: Freshworks Inc. (2025). Retrieved from https://www.freshworks.com/.

Indicative timeline: 6–12 months (pilot in customer service + technical operations; scale to all districts).

Web-Based Virtual Office (Remote Service Portal) and Mobile App (12–18 months).

The Virtual Office refers to a web-based remote service portal that allows citizens to access administrative services online without requiring physical visits to the utility offices.

Problem: Limited 24/7 access to services; dependence on in-person channels and office hours.

Solution: A Virtual Office (web) plus a mobile app to enable self-service: filing requests and claims, balance/consumption queries, online payments, and status tracking, following regional peer practices.

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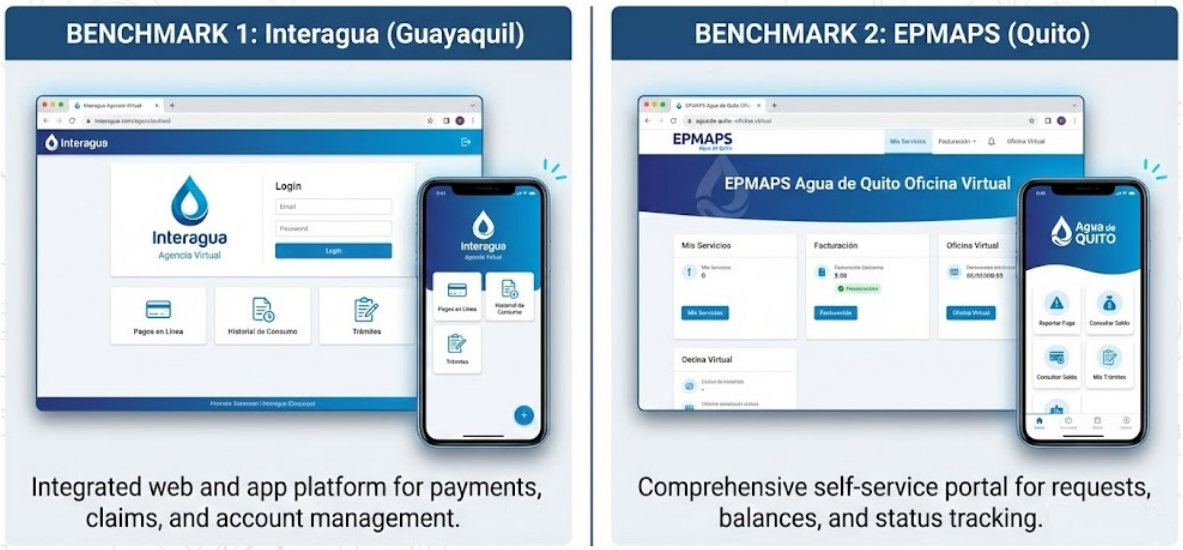
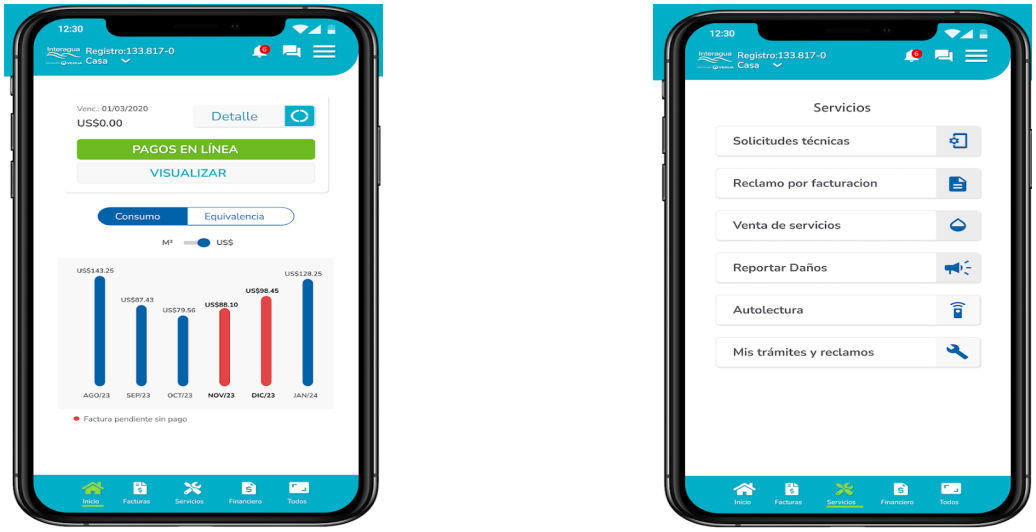


Figure 2. Examples of Virtual Office and mobile self-service portals implemented by Ecuadorian public utilities, serving as benchmarks for the proposed solution [21,22].

Implementation details: Responsive web portal and mobile apps (Android/iOS); single sign-on; integration with ERP (accounts, invoices, receipts), payment gateways, and the CRM (ticketing); accessibility best practices; analytics for usage and conversion. The proposed design draws inspiration from the *Interagua By Veolia* mobile application, which enables users to review and pay water consumption bills, report service incidents, and submit technical or billing claims directly from their smartphones. Its interface (see Figure 3) demonstrates an intuitive layout, integrating financial and service modules that simplify access to real-time account information and service requests.



(a) Consumption and billing view and payment options.

(b) Service menu with technical requests and remote services

Figure 3. Representative interfaces of the *Interagua By Veolia* mobile application available on PlayStore, illustrating digital features such as online payments, service management, and technical request submission.

Indicative timeline: 12–18 months (web first, mobile next).

Virtual Agent/Chatbot for Tier-1 Support (6–9 months).

Problem: High load on phone lines and front desks for repetitive inquiries; slow first-contact resolution.

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Solution: A 24/7 virtual assistant integrated into the Virtual Office and mobile app to address FAQs, guide procedures, capture tickets, and escalate complex cases to human agents. This tool emulates successful implementations such as the virtual assistant *IRIS* of Interagua, which allows customers to interact through chat and WhatsApp channels, receive immediate answers, and even process service requests remotely. Such systems improve accessibility, reduce waiting times, and strengthen citizen engagement through continuous digital interaction.

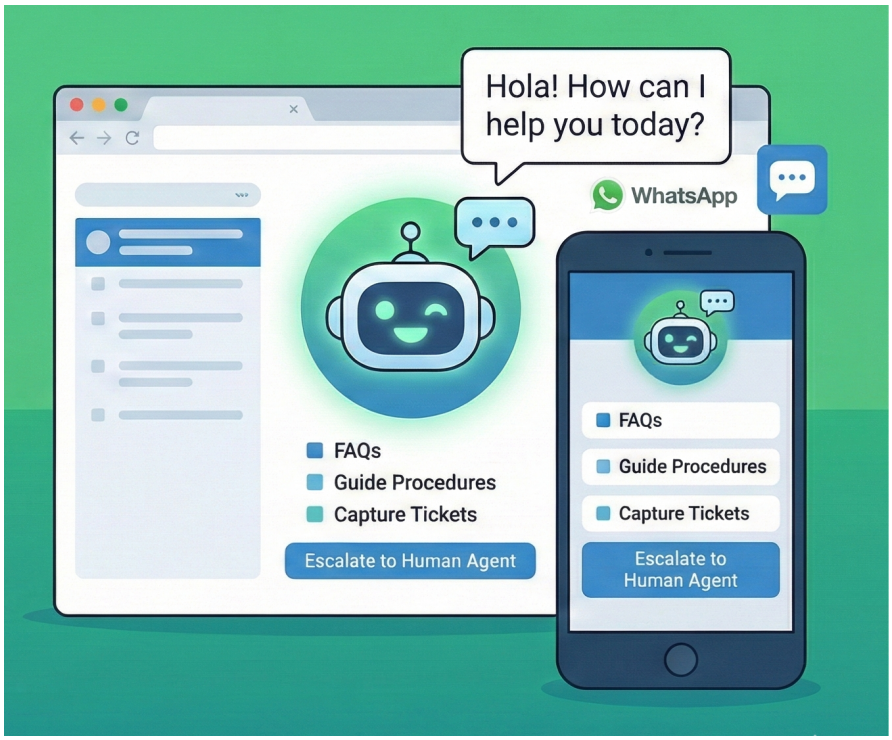

Figure 4. Example of a virtual assistant (*IRIS*, Interagua By Veolia) used for automated customer interaction, enabling users to resolve inquiries, report service issues, and access support 24/7 via chat or WhatsApp. *Note: The interface includes mixed Spanish and English labels, reflecting the multilingual configuration of the deployed application.*

Implementation details: Conversational flows for the top 20 intents (balances, payments, outages, leak reporting, meter procedures); automatic routing to human agents in the CRM; integrated monitoring of containment rate and user satisfaction. In the context of the proposed digital transformation, a similar chatbot would manage first-tier interactions, such as balance queries, billing support, or service scheduling, through channels like the web portal, mobile app, or WhatsApp integration, ensuring constant availability and secure communication with customers.

Indicative timeline: 6–9 months (MVP with iterative training based on real user interactions and feedback loops) [20] .

Mobile Meter-Reading and Field Apps (rolling deployment).

Problem: Paper-based meter reading and manual data capture introduce delays and transcription errors that affect billing cycles.

Solution: Android field app with GPS, camera, and OCR to capture readings, photos, and anomalies in real time, with route assignment and validation rules. This approach follows the experiences of Ecuadorian municipal utilities such as EMAPAL in Azogues, where mobile technologies have replaced manual processes for field data collection, improving accuracy and reducing processing time [23]. The system allows real-time synchronization with the billing database and includes geographic tagging of readings for verification and route optimization.

Implementation details: Route planning and assignment; offline and online synchronization; GPS geotagging for each reading; anomaly detection based on consumption trends (e.g., zero or

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abnormally high values); automatic upload to the commercial and billing system; and secure audit trails to prevent manipulation of data [23]. As illustrated in Figure 5, this digital process eliminates the need for paper logs and allows operators to record data efficiently using mobile devices equipped with built-in validation mechanisms.

Figure 5. Example of a mobile meter-reading application for water utilities, used to capture field data directly from meters with geolocation and photo verification features.

Indicative timeline: Rolling implementation by route sectors (every 4–6 weeks) until achieving 100% operational coverage, with a total deployment time of approximately 4–6 months.

e-Invoicing and Digital Receipts (3–6 months).

Problem: Paper-based invoicing and scattered receipts slow down collections, increase paper consumption, and raise operational costs due to manual reconciliation and physical document handling.

Solution: Implement an e-invoicing system compliant with national tax authority standards, integrated with the ERP and Virtual Office/mobile platforms. The system would automatically generate digital invoices, send them via secure channels (email or SMS), and archive them in an electronic repository accessible to both customers and internal auditors. This modernization aligns with the broader trend of digital transformation in Ecuadorian utilities, promoting transparency and efficiency in revenue management. As shown in Figure 6, mobile integration enables users to view and pay their invoices directly from their smartphones, improving the timeliness and traceability of payments.

Implementation details: Partnership with a certified e-invoicing provider authorized by the national tax authority; encrypted digital document storage with retrieval capabilities for customers and auditors; automated dispatch via email and SMS; integration with ERP modules for payment reconciliation and customer records; and dashboards for monitoring payment behavior and overdue accounts. The system would also include a digital consent process to ensure regulatory compliance and user transparency throughout billing operations.

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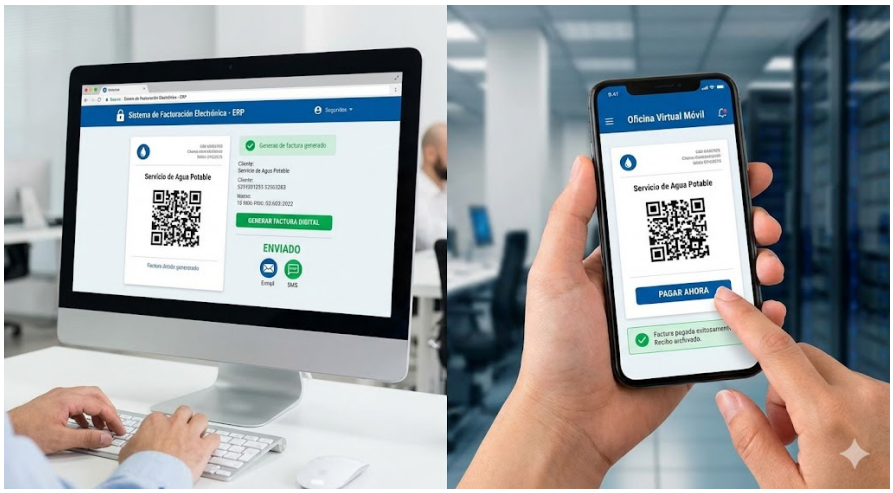

Figure 6. Example of a mobile interface for online payment and digital invoicing, demonstrating how e-billing integration enhances customer accessibility and operational efficiency.

Indicative timeline: 3–6 months, including provider selection, pilot implementation, and progressive migration from paper-based to fully digital invoicing.

Continuous Training and Change Management (transversal, 12 months).

Problem: Intermediate ICT proficiency and pockets of resistance jeopardize adoption and benefits realization .
Solution: A structured program of role-based training and change enablement aligned to each deployment wave .
Implementation details: Training paths for agents, dispatchers, field crews, supervisors; microlearning content embedded in tools; super-user network; communication plan; adoption KPIs (active users, task success, satisfaction) .
Indicative timeline: 12 months (aligned to Blocks A–G), then quarterly refreshers .

Table 6. Problem –Solution–Implementation–Time (PSIT) matrix for the proposed ICT portfolio.

Problem	Solution	Implementation details
Aging devices; uneven peripherals	Infrastructure refresh	Standard image; warranty SLAs; endpoint protection; staged rollout
Manual request handling; low visibility	Case/CRM	Multichannel intake; auto-routing; SLAs; dashboards; ERP integration
Limited 24/7 access	Virtual Office + Mobile	Self-service; payments; status tracking; SSO; ERP/payment/CRM integration
High Tier-1 load	Virtual agent	FAQ flows; escalation to agents; containment/SAT monitoring
Paper meter-reading	Field app	Routes; GPS/OCR; anomaly flags; online/offline; billing integration
Low spatial awareness	GIS	Asset layers; incidents; field capture; linkage to CRM and ops data
Paper invoicing	e-Invoicing	Certified provider; digital delivery; reconciliation dashboards
Skills/resistance	Training & change	Role-based curricula; super-users; adoption KPIs; comms plan

Cybersecurity and Data Protection Governance (transversal, 6–12 months).

Problem: The baseline diagnostic identified limited cybersecurity capabilities, including the absence of formal data protection policies, basic security procedures, and staff awareness mechanisms.

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The increased use of digital platforms (CRM, Virtual Office, mobile apps, and e-invoicing) raises the risk of data breaches, service disruptions, and non-compliance with personal data protection regulations.

Solution: Implement a basic but robust cybersecurity and data protection governance layer aligned with the scale and resources of a small municipal public utility. This includes the adoption of access control mechanisms, secure data storage, encrypted communications, backup policies, and compliance-oriented data management procedures.

Implementation details:

- *Access control and identity management:* Role-based access control (RBAC) implemented within the ERP system and CRM platform, combined with strong password policies and multi-factor authentication where supported.
- *Secure communications and hosting:* Use of HTTPS/TLS encryption for all web-based services; deployment on secure cloud or on-premise environments with firewall protection (e.g., *UFW* or *pfSense*).
- *Data backup and recovery:* Automated daily backups using tools such as *Veeam Backup*, *Bacula*, or cloud-native backup services, with periodic restore testing.
- *Endpoint protection:* Installation of basic endpoint security solutions (e.g., *Microsoft Defender*, *Sophos Endpoint*) on all workstations.
- *Policy and regulatory compliance:* Definition of internal data protection and information security policies aligned with national personal data protection regulations, including data minimization, purpose limitation, consent, and controlled data retention.
- *Staff awareness and procedures:* Short cybersecurity awareness training sessions focused on phishing prevention, secure password usage, and proper handling of citizen data.

Indicative timeline: 6–12 months, executed in parallel with the deployment of digital services, with priority on access control, secure communications, and backup mechanisms during the first implementation phase.

4.3. Performance Analysis Using KPIs

The KPI values reported in this section correspond to empirically observed pre-digitalization performance, obtained from institutional records, service logs, direct observation, and interviews conducted over a three-month diagnostic window. All post-intervention values presented in this Section are explicitly treated as ex ante projections derived from process redesign analysis, benchmarking, and scenario-based estimation, rather than measured post-implementation outcomes.

4.3.1. Average Response Time to Requests (KPI 1)

The Average Response Time (ART) to citizen requests measures the speed with which the public utility manages and resolves service demands—from registration to closure. This KPI is a fundamental indicator of operational efficiency, service quality, and citizen satisfaction. The baseline assessment revealed multiple weaknesses affecting response times, particularly in customer service and technical operations.

Current Situation (Before Digitalization).

At the time of the diagnostic, the organization's response capacity was limited by obsolete infrastructure, manual workflows, and fragmented communication channels. On average, the institution required **48 hours** to process general service requests. Most interactions occurred through traditional channels (in-person or telephone), which constrained throughput and created administrative bottlenecks.

At the time of the study, the municipal utility did not operate an integrated digital ticketing or case-management system. Therefore, this value was obtained through the triangulation of historical administrative records, manual service logs maintained by customer service and technical departments,

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and information provided during the semi-structured interview with the Head of the Information Technology Department.

Other critical issues included: (i) a lack of a centralized digital platform for request registration and tracking, (ii) non-standardized workflows without ticket prioritization or assignment rules, (iii) manual task distribution among technicians, and (iv) insufficient communication with users, who often had to visit offices to verify the status of their requests. The absence of digital automation resulted in low transparency, redundant manual work, and extended service times.

Expected Situation (After ICT Implementation).

Following the deployment of a *Customer Relationship Management (CRM)* system integrated with a Virtual Office, mobile app, and chatbot, a substantial improvement in response efficiency is expected. Automation of registration, assignment, and monitoring will streamline both administrative and technical processes. The proposed ICT architecture enables users to file and track requests 24/7, improving accessibility and service transparency.

Specifically, the expected outcomes include:

- Reduction of the average response time from **48 hours to 12 hours** for general requests.
- Centralized management of cases through a CRM that automatically routes requests to responsible departments.
- 24/7 service availability via Virtual Office and mobile applications.
- Automatic prioritization of technical requests based on urgency and geographic location.
- Real-time ticket tracking by citizens through unique identifiers.
- Reduction of repetitive administrative workloads, allowing staff to focus on value-added activities.

These improvements directly impact operational efficiency, reduce citizen waiting times, and promote greater transparency in service management.

The comparison in Table 7 summarizes the baseline values and the projected post-implementation scenario derived from process redesign and benchmarking assumptions. Under these assumptions, a 75% reduction in response time is anticipated, which could improve citizen experience and operational coordination if the CRM, Virtual Office, and monitoring mechanisms are effectively deployed and adopted.

Table 7. Comparison of KPI — Average Response Time to Requests (baseline vs. projected post-implementation).

Indicator	Before Automation (Baseline)	Projected After ICT Implementation
Average response time to requests	48 hours	12 hours
Requests managed in less than 24 hours	30%	85%
Automated requests	10%	80%
Main service channels	In-person and telephone	Digital (chatbot, mobile app, CRM)

4.3.2. Administrative Processing Time (KPI 2)

The Administrative Processing Time (APT) evaluates how efficiently administrative procedures are completed, from the receipt of a request to its final resolution. This KPI directly reflects the organization's ability to streamline operations through process automation and document digitalization, which are essential for improving citizen experience and reducing administrative burdens.

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Current Situation (Before Digitalization).

The baseline assessment revealed that administrative procedures in the institution remain largely dependent on manual operations, printed documentation, and in-person interactions. The average time required to complete an administrative process was approximately **72 hours**.

Since administrative procedures were predominantly manual and paper-based, processing times were reconstructed using internal administrative records, manual workflow registries, and staff-reported averages collected through interviews with key personnel, particularly the Head of the Information Technology Department.

Several critical inefficiencies were identified:

- **Physical documentation:** Most processes require manual signatures, printing, and filing, slowing down workflows and generating document backlogs.
- **High dependence on in-person procedures:** Citizens must visit offices to submit or collect documents, which increases waiting times and saturation at customer service desks.
- **Lack of automation:** Absence of an integrated digital system to manage and monitor administrative workflows leads to data duplication, loss of records, and human error.
- **Heavy operational workload:** Staff must manually process requests and paperwork, reducing their capacity to focus on strategic tasks.
- **Limited traceability:** Citizens cannot track the status of their requests online, resulting in repeated calls or visits for updates.

Expected Situation (After ICT Implementation).

After implementing a Virtual Office platform, document digitalization tools, and workflow automation within the ERP system, a substantial improvement in efficiency is expected. The institution will be able to process administrative procedures faster, provide 24/7 online service, and significantly reduce operational costs.

The anticipated improvements include:

- Reduction of the average processing time from **72 hours to 24 hours**.
- Full digitalization of administrative documents through a document management platform, eliminating physical paperwork.
- Deployment of a 24/7 virtual service portal allowing citizens to complete procedures online without visiting the offices.
- Integration with the existing ERP system (“CABILDO”) to synchronize records, avoid duplication, and improve information traceability.
- Optimization of staff workload by automating repetitive validation and approval tasks.
- Online real-time tracking of the progress of administrative procedures via web or mobile app, eliminating unnecessary calls or visits.

These improvements will enable a more agile, transparent, and citizen-centered administration, aligning with modern e-governance standards in the public utilities sector.

As summarized in Table 8, the proposed digital workflow and Virtual Office are associated with a *projected* reduction in administrative processing time from 72 to 24 hours (i.e., an estimated 66% decrease) under the post-implementation scenario. These values should be interpreted as *ex ante* estimates that depend on successful document digitalization, workflow automation, and organizational adoption (training, governance, and enforcement of standardized procedures).

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Table 8. Comparison of KPI — Administrative Processing Time (baseline vs. projected post-implementation).

Indicator	Before Automation (Baseline)	Projected After ICT Implementation
Average administrative processing time	72 hours	24 hours
Digitalized administrative procedures	20%	90%
Users completing procedures online	15%	80%
Administrative workload level	High (manual processes)	Optimized (automated workflows)
Method for procedure inquiries	In-person or telephone	Digital (web portal, app, chatbot)

4.3.3. Number of Digital Transactions (KPI 3)

The Number of Digital Transactions (NDT) measures the volume of procedures, payments, and service requests processed through digital platforms compared with traditional in-person channels. This KPI reflects the degree of digital adoption by citizens and the effectiveness of ICT integration in administrative and service processes.

Current Situation (Before Digitalization).

The baseline evaluation indicated that the institution exhibited a very low level of digital adoption, relying predominantly on in-person and manual transactions. The lack of integrated platforms for digital payments and online requests limited operational efficiency and citizen accessibility. The main challenges identified were:

- **High dependency on physical presence:** Most payments and service requests were processed directly at customer service offices, creating long queues and service congestion.
- **Absence of a unified platform:** The organization did not have a Virtual Office or mobile application capable of centralizing payments, requests, and complaint management.
- **Limited digital literacy among users:** A portion of citizens preferred traditional channels due to unfamiliarity with digital tools.
- **Manual reconciliation:** Payment and billing records were processed separately in different systems, increasing the administrative workload and reconciliation errors.

As a result, less than 20% of all operational transactions were performed digitally, and more than 80% required direct staff interaction, either in person or by phone.

Expected Situation (After ICT Implementation).

With the introduction of the Virtual Office, mobile applications, and integrated online payment gateways, a significant increase in the number of digital transactions is expected. The proposed solution allows citizens to perform self-service operations anytime and anywhere, thereby decentralizing service provision and improving convenience. The expected improvements include:

- **Decentralization of administrative services:** Over 80% of processes will be available online, reducing the pressure on physical service offices.
- **Availability of a self-service portal:** Users will be able to make inquiries, payments, and claims directly through digital channels without visiting the utility offices.
- **Online payment integration:** Payment gateways (e.g., national providers compatible with ERP systems) will enable real-time billing and automatic confirmation of payments.
- **Enhanced citizen confidence:** Awareness and education campaigns will promote the use of digital tools and ensure inclusiveness in technology adoption.

The full implementation of these systems will not only increase operational efficiency but also promote transparency and accountability by providing real-time digital records of every transaction.

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As shown in Table 9, the roadmap estimates an increase in the share of digital transactions from 20% to 85% (i.e., a 4.25-fold rise) in the projected scenario. If achieved, this shift could reduce congestion at service offices, improve traceability through digital records, and support more user-oriented service delivery. However, realization of these outcomes will depend on platform usability, citizen digital literacy, availability of payment gateways, and sustained communication and inclusion campaigns.

Table 9. Comparison of KPI — Number of Digital Transactions (baseline vs. projected post-implementation).

Indicator	Before Automation (Baseline)	Projected After ICT Implementation
Share of digital transactions	20%	85%
Access channel for payments and requests	In-person at offices	Virtual Office and mobile app
Availability of online payment system	Not available	Fully integrated payment gateway
Administrative workload from manual processing	High	Significantly reduced
Citizen adoption of digital services	Low	High (with awareness campaigns)

4.3.4. Citizen Satisfaction with the Digitalization of Services (KPI 4)

This KPI evaluates citizens' perceptions and acceptance regarding the proposed implementation of ICT-enabled services in the organization's administrative and customer service processes. Its purpose is to measure the perceived impact of digital transformation on the quality of service, accessibility, and operational efficiency. As citizen feedback is a central dimension of public management performance, this KPI provides valuable insights into how technological modernization influences public trust, satisfaction, and service perception.

The analysis was based on a structured satisfaction survey conducted among service users, designed to assess acceptance levels, perceived benefits, and willingness to adopt digital channels such as the Virtual Office, mobile applications, chatbots, and electronic invoicing. The results revealed a clear and positive response from citizens, demonstrating a high level of openness toward digitalization and automation as key drivers of better service delivery.

Response Distribution Analysis.

Table 10 presents the frequency distribution of responses for the main satisfaction-related items. The results show a strong concentration of responses in the upper categories of the 5-point Likert scale, specifically Agree (A) and Strongly Agree (SA), indicating a predominantly positive perception toward the digitalization of services.

Table 10. Frequency distribution of citizen satisfaction responses (selected items).

Item	SD	D	N	A	SA
ICT improves service quality	2.1%	3.4%	6.5%	41.0%	47.0%
Digitalization speeds procedures	3.2%	6.1%	12.0%	24.7%	54.0%
24/7 digital services are necessary	1.6%	2.4%	8.6%	39.4%	48.0%
Preference for electronic invoicing	1.0%	1.8%	2.2%	30.0%	65.0%
Use of chatbots for inquiries	4.7%	9.2%	38.8%	27.3%	20.0%

Note: SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree.

Descriptive Statistics and Confidence Intervals.

To complement percentage-based results, mean scores, standard deviations, and 95% confidence intervals were calculated for each satisfaction construct. As shown in Table 11, all mean values are well above the neutral midpoint of the scale (value = 3), confirming a favorable overall evaluation.

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Table 11. Descriptive statistics and confidence intervals for satisfaction indicators.

Indicator	Mean	SD	95% CI
Service quality improvement	4.31	0.78	[4.23, 4.39]
Process acceleration	4.02	0.89	[3.93, 4.11]
Digital self-service adoption	4.05	0.84	[3.96, 4.13]
Chatbot acceptance	3.62	0.91	[3.53, 3.71]
Electronic invoicing preference	4.68	0.61	[4.62, 4.74]

A one-sample t-test was conducted to evaluate whether the observed mean satisfaction scores differed significantly from the neutral reference value of the Likert scale ($\mu = 3$). All indicators showed statistically significant differences ($p < 0.001$), indicating that citizens' attitudes and acceptance toward the proposed digital transformation initiatives are significantly positive relative to the neutral midpoint.

Summary of Findings.

The citizen satisfaction survey revealed a predominantly positive perception toward the digital transformation of the utility's administrative and customer service processes. Overall, the results indicate high acceptance of ICT-based modernization and a clear willingness to adopt new digital tools. A large majority (**88%**) of respondents believed that technological upgrades would improve customer service, while **54%** strongly agreed that digitalization would accelerate administrative procedures. Nearly half (**48%**) supported automation of key operational tasks, such as leak reports and service installations, and **87.4%** emphasized the need for 24/7 availability of online services. A remarkable **95%** of participants preferred to receive invoices in digital format, confirming a widespread inclination toward paperless, efficient, and environmentally sustainable administrative processes. Finally, chatbots were positively received, with **47.3%** of users stating that they would use them to solve frequent inquiries

In summary, the survey results support the relevance and social acceptance of implementing ICT solutions in public service delivery. They indicate that citizens are receptive to technological innovation and perceive digitalization as a key enabler of improved accessibility and service quality.

5. Discussion

5.1. Impact of Digital Transformation on Administrative Efficiency

This discussion distinguishes explicitly between empirically observed findings and projected performance improvements derived from the proposed ICT-based digital transformation roadmap. Such a distinction is necessary to ensure analytical rigor and to avoid conflating validated evidence with scenario-based estimates.

From an empirical perspective, the primary validated findings stem from the citizen satisfaction survey. The results indicate a strong positive perception of ICT integration, with more than 88% of respondents agreeing that digital tools improve service quality and 82% expressing a preference for electronic invoicing. These outcomes constitute direct empirical evidence of social acceptance and readiness for digital service adoption, supporting the relevance of the proposed transformation strategy.

In contrast, the operational efficiency indicators—Average Response Time (ART), Administrative Processing Time (APT), and Number of Digital Transactions (NDT)—represent projected outcomes based on baseline measurements, process analysis, and benchmarking against comparable public utilities. These projections were derived from the comparison between current manual workflows and the expected performance of integrated digital platforms such as CRM systems, Virtual Offices, and mobile applications.

Specifically, the Average Response Time (ART) is projected to decrease by approximately 75%, from 48 hours to 12 hours, as a result of automated case registration, prioritization, and real-time monitoring. Similarly, the Administrative Processing Time (APT) is expected to be reduced from 72 hours to 24 hours through document digitalization, workflow automation, and ERP integration. The

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Number of Digital Transactions (NDT) is projected to increase from 20% to 85%, reflecting a shift toward self-service digital channels and reduced dependence on in-person interactions.

While these projected improvements are grounded in documented baseline conditions and validated experiences from comparable municipal utilities, they should be interpreted as *scenario-based performance estimates* rather than empirically observed post-implementation results. Their value lies in illustrating the potential operational impact of the proposed ICT roadmap and in supporting decision-making for digital investment and planning.

Overall, the discussion highlights that the digital transformation initiative combines empirically validated citizen acceptance with analytically grounded performance projections. This dual evidence base supports the feasibility and relevance of the proposed transformation while underscoring the need for future longitudinal studies to empirically validate KPI outcomes following full implementation.

5.2. Risk Analysis and Alternative Implementation Scenarios

Although the projected performance improvements represent an optimistic scenario, their realization is subject to several organizational, technological, and contextual risks. The studied municipal public utility operates with aging end-user hardware, limited human resources, and intermediate levels of digital skills, which may affect the pace and effectiveness of ICT adoption. Additionally, resistance to change, budgetary constraints, and regulatory or legislative requirements may delay or limit the full deployment of the proposed solutions.

To address these uncertainties, three alternative implementation scenarios are considered. In a conservative scenario, partial ICT adoption and limited staff training would result in more moderate improvements, such as a 40–50% reduction in response and processing times and digital transaction rates below 60%. A moderate scenario, assuming phased infrastructure upgrades and targeted training programs, would enable intermediate gains, with efficiency improvements between 55–65% and digital transactions reaching approximately 70%. The optimistic scenario, reflected in the KPI projections reported in Section 4.3, assumes adequate financial support, effective change management, and full integration of CRM, Virtual Office, and mobile platforms, leading to the maximum projected benefits.

This scenario-based analysis highlights that the reported KPI values should be interpreted as upper-bound estimates rather than guaranteed outcomes. It also reinforces the importance of risk mitigation strategies, including phased implementation, continuous staff training, stakeholder engagement, and regulatory alignment, to ensure sustainable and realistic digital transformation in municipal public utilities.

5.3. Comparative Analysis with Similar Public Utilities

The expected outcomes of the proposed digital transformation in the studied municipal utility align closely with regional experiences of ICT implementation in public sector services across Latin America. This alignment reinforces common patterns identified in the literature—particularly with respect to administrative efficiency, transparency, and responsiveness.

In the Ecuadorian context, several municipalities and public service organizations have undertaken similar initiatives. For example, Paredes-Parada et al. [24] document the implementation of integrated ERP systems and administrative analytics in Ecuadorian higher education institutions, which led to measurable improvements in process coordination and efficiency. While the sector differs, the operational complexity and institutional challenges are comparable to those of municipal utilities, supporting the relevance of ERP-based solutions in this case study.

On a broader regional level, Martínez-Pérez and Rodríguez-Abitia [25] propose a structured roadmap for digital transformation in Latin American public institutions. Their model emphasizes three pillars—organizational readiness, infrastructure modernization, and governance frameworks—all of which are addressed in the present case through staged implementation (infrastructure renewal, CRM deployment, Virtual Office platform, and user training). This confirms the scalability of such frameworks to local municipal environments.

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Additionally, Carlsson et al. [15] highlight how inter-municipal collaboration in Sweden can help overcome disparities in resources and technological maturity, offering an alternative path to digital maturity through collective digital action. Although situated in a different geopolitical setting, the underlying principle—leveraging collaboration to mitigate structural gaps—is transferable and supports strategies for smaller municipalities in Latin America seeking to build capacity through shared digital platforms.

These comparative cases suggest that targeted digital investments, combined with pragmatic project management and gradual implementation, can lead to substantive improvements in municipal service delivery—even in contexts with limited resources. By integrating proven tools like CRM systems, mobile apps, and Virtual Offices, and by adopting modular implementation strategies aligned with regional best practices, the studied utility is positioned to replicate similar success outcomes documented in both national and international public sector cases.

5.4. Theoretical Implications

This study contributes to the theoretical discourse on digital transformation in the public sector by refining how existing e-government and digital governance frameworks can be operationalized at the level of municipal public utilities. Rather than proposing new theory, the research advances current conceptual models by translating abstract principles of digital transformation into concrete organizational processes and measurable performance dimensions.

While prior studies have primarily focused on policy alignment, institutional readiness, or national digital strategies, this work emphasizes the operational layer at which digital transformation unfolds in practice. By integrating organizational diagnosis, ICT solution design, and KPI-based performance modeling, the study provides a structured analytical approach that links socio-technical transformation theories with process-level implementation in public service organizations.

Importantly, the contribution of this study lies in its conceptual and methodological clarification of how digital transformation can be assessed in contexts where full post-implementation data are not yet available. The proposed framework demonstrates how baseline measurements, citizen perception data, and analytically grounded performance projections can be jointly used to evaluate digital transformation initiatives in a systematic and transparent manner.

Furthermore, the findings reinforce theoretical perspectives that conceptualize digital transformation as a socio-technical phenomenon, highlighting the interaction between technology adoption, organizational capabilities, and user acceptance. The empirically observed citizen satisfaction results support the relevance of user-centered approaches within digital governance theory, while the KPI-based projections illustrate how efficiency-oriented constructs are expected to evolve following ICT integration.

5.5. Practical Implications

From a practical perspective, this study offers actionable insights for public managers, policy-makers, and municipal decision-makers seeking to implement digital transformation initiatives in resource-constrained environments. The proposed ICT improvement plan provides a structured and modular roadmap that can be adapted to the specific operational realities of municipal public utilities, particularly those responsible for essential services.

The empirical evidence generated through KPI-based evaluation demonstrates how targeted ICT investments—such as CRM systems, Virtual Offices, mobile applications, and e-invoicing—can lead to measurable improvements in administrative efficiency, service responsiveness, and citizen satisfaction. These findings support informed decision-making by enabling managers to prioritize digital initiatives based on expected operational impact rather than on technological trends alone.

Additionally, the study highlights the importance of integrating technological solutions with organizational change management and staff training. The identification of skill gaps and resistance factors underscores the need for continuous capacity-building to ensure sustainable adoption and long-term benefits. By emphasizing performance monitoring and user feedback, the proposed frame-

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work enables public organizations to track progress, adjust implementation strategies, and enhance accountability.

5.6. Governance Mechanisms for Transparency, Accountability, and Trust

Improvements in transparency and citizen trust are not assumed to arise automatically from the introduction of digital channels, but rather from specific governance mechanisms enabled by the proposed ICT solutions. In this study, such mechanisms are explicitly embedded in the design of the digital transformation roadmap:

1. Traceability and auditability are strengthened through the CRM-based case management system, which records timestamps, responsible units, service-level agreements, and resolution outcomes for each request. This creates auditable service histories that support internal accountability and external oversight.
2. Complaint-resolution loops are formalized by integrating citizen feedback and service closure confirmation into the CRM workflow, ensuring that unresolved or delayed cases are systematically escalated and monitored.
3. Data governance and cybersecurity practices—such as role-based access control, encrypted communications, backup procedures, and data retention policies—contribute to institutional reliability and protection of personal information, which are essential preconditions for trust in digital public services.

Finally, dashboard-based reporting of KPIs (e.g., response time, resolution rate, digital transaction rate) enhances managerial transparency by making service performance visible and comparable over time.

6. Conclusions

This study provides a structured diagnostic assessment and an ICT-based digital transformation roadmap for administrative process optimization in a municipal public utility. Rather than evaluating implemented technological changes, the research combines organizational diagnosis, baseline performance characterization, and citizen perception analysis to inform the design of a feasible and context-sensitive digital modernization strategy.

The empirical evidence generated by this study consists of two main components: (i) a diagnostic analysis of existing administrative processes and ICT capabilities, based on direct observation and a semi-structured interview with the head of the IT department, and (ii) a citizen survey capturing attitudes, expectations, and acceptance of proposed digital services. These findings reveal clear technological and procedural gaps, alongside a high level of citizen readiness to adopt digital channels such as Virtual Offices, electronic invoicing, and automated service support.

Projected performance improvements—such as the anticipated reduction in average response time and administrative processing time, and the expected increase in digital transaction rates—are explicitly treated as ex ante estimates. These projections are derived from baseline records, process redesign analysis, and benchmarking against comparable public utilities, rather than from post-implementation measurements. As such, they should be interpreted as plausible performance scenarios contingent upon effective implementation, adequate resource allocation, and sustained organizational commitment.

The analysis further confirms that digital transformation in public utilities is a socio-organizational process, not merely a technological intervention. Intermediate levels of ICT proficiency and generally positive attitudes toward modernization constitute enabling conditions; however, the realization of projected benefits depends on structured change-management strategies, continuous staff training, and governance mechanisms that support adoption and institutional learning.

Finally, this research contributes a transparent and replicable framework for planning digital transformation initiatives in resource-constrained municipal utilities. Future research should prioritize longitudinal and multi-actor evaluations, incorporating post-implementation KPI measurements and

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perspectives from multiple organizational levels, in order to empirically validate the performance impacts anticipated in this study.

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Institutional Review Board Statement: Ethical review and approval were waived for this study by the Ethics Committee of the State Technical University of Quevedo, Ecuador, due to the non-interventional nature of the research. The study was based on an anonymous survey conducted with adult participants, involved minimal risk, collected no personal or sensitive data, and was carried out exclusively for academic research purposes, in accordance with national regulations and institutional ethical guidelines.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Participation was voluntary, and respondents were informed about the objectives of the research, the anonymous treatment of data, and its exclusive use for academic purposes prior to completing the survey.

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References

1. Naccari Carlizzi, D. Public Administration Reengineered Applying AI Models Towards Precision Governance. In *Lecture Notes in Networks and Systems*; 2025; Vol. 880, pp. 61–84. https://doi.org/10.1007/978-3-031-73880-7_6.
2. Saeedikiya, M.; Salunke, S.; Kowalkiewicz, M. The nexus of digital transformation and innovation: A multilevel framework and research agenda. *Journal of Innovation and Knowledge* **2025**, *10*, 100640. https://doi.org/https://doi.org/10.1016/j.jik.2024.100640.
3. Cho, S.; Hur, J.; Kim, D. Bridging trust in AI and its adoption: The role of organizational support in AI chatbot implementation in Korean government agencies. *Government Information Quarterly* **2025**, *42*. https://doi.org/10.1016/j.giq.2025.102081.
4. Vesolovska, M.; Karkovska, V.; Duma, O. Artificial intelligence in public administration: how the emotional intelligence of civil servants influences its effective implementation. *Administratie Si Management Public* **2025**, *2025*, 27–45. https://doi.org/10.24818/amp/2025.45-02.
5. Criado, J.I. Digital Public Administration in Latin America: Digitalization, Public Innovation, and the Future of Technologies in the Public Sector. In *Emerald Handbook of Public Administration in Latin America*; 2021; pp. 343–374. https://doi.org/10.1108/978-1-83982-676-420201014.
6. Prieto, E.; Galarza, I.; Guevara, A.; Sanchez, S.; Calderón, R. Governance Model for Artificial Intelligence in the Public Sector of Guayaquil, Ecuador, 2024. *Journal of Ecohumanism* **2024**, *3*, 12850–12859. https://doi.org/10.62754/joe.v3i8.6113.
7. Kesar, B.; Joseph, S. Navigating the digital wave: equipping public officials for technology-driven governance. In *Digital Competency Development for Public Officials Adapting New Technologies in Public Services*; 2025; pp. 251–280. https://doi.org/10.4018/979-8-3693-6547-2.ch010.
8. Febiri, F.; Gariba, M.; Hub, M.; Provaznikova, R. The synergy between human factors, public digitalization and public administration in the European context. *Journal of Open Innovation: Technology, Market, and Complexity* **2024**, *10*. https://doi.org/10.1016/j.joitmc.2024.100424.
9. Hassani, S.; Babazadeh Sangar, A. Digital transformation of Tabriz, Iran by IoT adoption. *Information Development* **2024**, *42*, 511–528. https://doi.org/10.1177/02666669231219795.
10. Qi, F.; Zhang, P.; Zhang, M.; Guo, D. How does digital transformation promote residents' consumption upgrading? - Evidence from China's supply and demand restructuring. *Habitat International* **2026**, *168*. https://doi.org/10.1016/j.habitatint.2025.103679.

 doi:10.20944/preprints202602.1010.v1

11. Sagala, G.H.; Őri, D. Exploring the Strategy of E-Government Inclusion in Developing Countries. In Proceedings of the Electronic Government and the Information Systems Perspective; Kő, A.; Buccafurri, F.; Kotsis, G.; Tjoa, A.M.; Khalil, I., Eds., Cham, 2026; pp. 72–87.
12. Nyadzi, B.; Morris, J. E-Government and Public Trust in Developing Countries: A Systematic Review and Research Agenda. *International Journal of Public Administration* **2026**. https://doi.org/10.1080/01900692.2025.2597453.
13. Saeed, M.; Abdulmuhsin, A.; Dajani, D. From novelty to necessity: Understanding CRM-driven service robot adoption in Iraqi restaurants through UTAUT3. *Journal of Innovation and Knowledge* **2026**, *13*. https://doi.org/10.1016/j.jik.2025.100916.
14. Juita, R.; Inan, D.; Santoso, B. Digital market adoption by underserved MSMEs in developing countries: Mediation and moderation by self-efficacy and trust. *International Journal of Information Management Data Insights* **2026**, *6*. https://doi.org/10.1016/j.jjimei.2025.100384.
15. Carlsson, F.; Lindström, N.; Sandberg, J. Digital Transformation Through Collective Social Action - How Resource Disparities Can be Leveraged in Inter-municipal Collaboration. In Proceedings of the Lecture Notes in Computer Science, 2026, Vol. 15944, pp. 34–53. https://doi.org/10.1007/978-3-032-01589-1_3.
16. Amade, M.; Mamede, H.; Reis, L.; Branco, F. Cybersecurity in the Digital Transformation of Small and Medium-Sized Enterprises: A Systematic Review of Frameworks and Challenges in Developing Countries with a Focus on Mozambique. In Proceedings of the Lecture Notes in Networks and Systems, 2026, Vol. 1717, pp. 433–443. https://doi.org/10.1007/978-3-032-10721-3_38.
17. Twabu, K.; Nakene-Mginqi, M. Blockchain smart contract efficiency as a use case for higher learning institutions to easily access student information with home affairs as well as the department of higher education. *Multidisciplinary Reviews* **2026**, *9*. https://doi.org/10.31893/multirev.2026135.
18. Xiong, B.; Yu, B. The nonlinear effects of e-government on total-factor carbon emission efficiency in 136 countries. *Environment Development and Sustainability* **2026**. https://doi.org/10.1007/s10668-025-07297-8.
19. Hernández Sampieri, R.; Fernández Collado, C.; Baptista Lucio, P. *Metodología de la investigación*, 6th ed.; McGraw-Hill Education: México D.F., México, 2014.
20. Freshworks Inc.. Freshdesk: Cloud-Based Customer Support Software. https://www.freshworks.com/freshdesk/, 2025. Accessed: 3 February 2026.
21. Interagua. Agencia Virtual - Interagua, 2026. Accessed: 3 February 2026.
22. EPMAPS - Agua de Quito. Oficina Virtual - Empresa Pública Metropolitana de Agua Potable y Saneamiento, 2026. Accessed: 3 February 2026.
23. Cuenca, J.; Ortega, J. Ingreso de lecturas de consumo de agua potable en EMAPAL-Azogues, a traves de dispositivos móviles. *Revista Científica y Tecnológica UPSE (RCTU)* **2017**, *4*, 85 – 90.
24. Paredes-Parada, W.; Del Pozo, F.; García González, S.E.; Ndea, C. Good ICT Practices for the Integral Development of Ecuadorian Universities. In *Advances in Intelligent Systems and Computing*; 2021; Vol. 1277, pp. 163–170. https://doi.org/10.1007/978-3-030-60467-7_14.
25. Martínez-Pérez, S.; Rodríguez-Abitia, G. A Roadmap for Digital Transformation of Latin American Universities. In *Lecture Notes in Educational Technology*; 2021; pp. 19–36. https://doi.org/10.1007/978-981-16-3941-8_2.