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STATISTICAL ANALYSIS OF DIGITAL TRANSFORMATION AND ITS INCIDENCE IN REDUCING THE USE OF PAPER IN A HIGHER EDUCATION INSTITUTION: A CASE STUDY

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Abstract

Reducing the carbon footprint of higher education institutions has become a global trend in recent years, as they are the axis of society's scientific and technological transformation that must be carried out with a sustainable approach. Among the many approaches that can contribute to this problem are the digital transformation of academic and administrative processes and its impact on reducing paper use. This study details the statistical analysis of the digital transformation process based on the modules and computer services implemented by the ICT department in a higher education institution and its incidence in reducing the use of paper by its teaching and administrative staff. For this purpose, an initial instrument was proposed, consisting of 18 ordinal, three categorical and two numerical variables. After applying statistical data processing and validation techniques, it was reduced to 13 ordinal variables, three categorical and two influential numerical variables. In addition, this study has proposed an appropriate statistical protocol for the design and extraction of information applicable in the context of higher education institutions, consisting of the techniques: Mahalanobis distances, confirmatory factor analysis, Kruskal-Wallis, Mann-Whitney's U and Wilcoxon tests. The results showed the power of confirmatory factor analysis as a technique for obtaining models to measure indirectly observed latent variables, such as perceptions of digital transformation and paper reduction. In addition, it was found that the modules, systems, and computer tools implemented in the institution significantly reduced the execution times for performing administrative and teaching tasks in the institution, and significant differences were identified in the perception of digital transformation and reduction of paper use among staff.

Keywords **–** Digital transformation, Paper use reduction, Sustainability, Carbon footprint reduction in universities.

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1. Introduction

Digital transformation is a global trend that aims to implement computer systems in institutions and companies that allow workers to perform their daily activities more efficiently and contribute to better data and information management. In this way, at international, regional, and local levels, organizations have implemented software and hardware that allow easy access to and management of their information. In the educational sector, universities are no exception, so several implementations have been carried out under different computing paradigms to allow teachers and administrative staff to manage all the documentation that is produced and even currently to allow the management of complex activities such as grade management, document management, use of virtual libraries, activities registration, among others (Gawel, Strykowski & Madias, 2022; Gordon, Kemerova, Bolsunovskaya & Osipov, 2023; Gracia-Villar, Alvarez, Brie, Miró-Vera & García-Villena, 2023; Kinchin, 2022; Muñoz-García, Alcántara-Manzanares & Medina-Quintana, 2022; Pozo-Muñoz, Martín-Gámez, Velasco-Martínez & Tójar-Hurtado, 2023; Somma, 2022; Uleanya, 2023). Even and primarily motivated by the COVID-19 pandemic experienced in recent years, the digital transformation of academic processes in higher education institutions has been significantly accelerated by the need to teach virtual classes and carry out most institutional activities remotely during the confinement period (Alenezi, 2023; Chatzipanagiotou & Katsarou, 2023; Chodak, Ciesielski, Grysztar, Kurasińska, Makeeva, Prygiel et al., 2023; Nygren, Alégroth, Eriksson & Pettersson, 2023; Perry, 2023; Pozos-Pérez, Herrera-Urizar, Rivera-Vargas & Alonso-Cano, 2023; Shestakova & Morgunov, 2023; Sonnenschein, Stites, Gursoy & Khorsandian, 2023).

For these reasons and many others, the digital transformation in higher education institutions has been carried out and has evolved following the evolution of the available hardware and software, presenting countless successes and failures that have not been adequately evaluated in most institutions (Guevara-Vega, Chamorro-Ortega, Herrera-Granda, García-Santillán & Quiña-Mera, 2020; Jácome-Ortega, Herrera-Granda, Herrera-Granda, Caraguay-Procel & Basantes-Andrade, 2019; Jácome-Ortega, Caraguay-Procel, Herrera-Granda & Herrera-Granda, 2020). The digital transformation process and the reduction of the use of paper in a higher education institution are variables that are difficult to observe and measure; therefore, there are currently no specialized instruments designed according to a rigorous statistical protocol. For this reason, this study proposes the creation of an instrument to measure the perception of digital transformation and the reduction of the use of paper in higher education institutions based on the opinion of its primary users, which are the teaching and administrative staff. This instrument was built from 18 ordinal opinion variables organized as two factors, three categorical and two numerical variables. The proposed instrument was designed and validated according to a rigorous statistical protocol, which included: data treatment using Mahalanobis distances; verification of validity and reliability using confirmatory factor analysis; tests of differences in unobserved latent variables using Kruskal-Wallis tests; and analysis of differences in task completion times using the Wilcoxon test. Applying the statistical protocol reduced the instrument to 13 ordinal questions, 6 for the digital transformation factor and 7 for the paper use reduction factor, which were selected based on their loadings and contribution to the factorial structure. In addition, this study proposes a statistical protocol for processing and extracting inferential information in sustainability assessment instruments for higher education institutions.

1.1. Related Works

In the research of (Lechuga-Nevárez, 2023), an analysis of the digital transformation in Victoria de Durango, Mexico, is presented. The work addressed 95 companies created by university entrepreneurs in a descriptive, explanatory, correlational, non-experimental design since there was no manipulation of variables and cross-section. The results showed that 61% of entrepreneurs need to be aware of the importance of using technology and digital transformation, which is why it is necessary to continue implementing sites that contribute to sustainability.

The study of (Ricardo, Parra, Borjas, Cobo & Cano, 2020) aimed to determine the potential of offering professional programs taught remotely to reduce the gaps in higher education, which is necessary to define strategies that influence the demand and supply of educational programs. To achieve this objective,

a mixed model (linear hierarchical) was used, using information collected from 451,358 students between 2016 and 2018, obtaining a mixed methodology as a result, visualizing discrepancies with different authors of the literature. Pérez García, Rodríguez-Sánchez, Pérez-García and Rodríguez-Sánchez (2022) analyzed the use of virtual spaces by teachers based on practice proposals for the incorporation of technology. The study was conducted from a non-experimental perspective, using a descriptive transactional nature. The results showed that sending and receiving documents were the most used activities. In addition, some barriers to Internet access were found. In this way, it is concluded that ICTs are not widely used by teachers in their practice, where virtuality is oriented towards instrumental aspects, which is why it generally does not allow the pedagogical proposals to contribute to a better teaching-learning process.

In 2022, Casero-Béjar and Sánchez-Vera (2022) conducted a study to analyze the perception of second-year university students in front of the virtual modality during COVID-19 confinement. For this purpose, a descriptive study was carried out through a questionnaire in which the ICT tools and students' points of view were projected. As a result, before implementing tools and ICTs, an improvement analysis for virtual education is required for teachers and students. This study was designed to analyze the teaching-learning of nursing in remote environments, taking into account the factors related to the use of digital platforms. The methods used included a descriptive, quantitative, and cross-sectional study with a sample of 245 students. The results demonstrated associated factors such as work and class organization, classroom communication, connectivity, and clear instructions; however, connectivity was a notable disadvantage.

In the study of Luna-Conejo and Luna-Nemecio (2022), virtual education was analyzed to obtain sustainability metrics regarding emotional and socio-ecological challenges. In order to achieve this goal, a bibliographical, qualitative documentary review was carried out. Using hermeneutic methods, it was found that motivation and emotional intelligence are key factors in developing skills that are essential resources for accessing knowledge.

The work of Arias-Corrales and Chao-Chao (2023) was carried out to compare the methodological adaptation and use of ICT in language teaching during the pandemic. It was performed by designing exploratory qualitative variables, based on a questionnaire to collect information for 2021 and 2022. The results showed that ICTs benefited from the exchange of information and communication since they allowed students to carry out their activities and save time by doing their activities at home. Finally, the resources and didactic materials could be easily shared by using digital tools. However, some disadvantages were also identified, such as an inability to access the Internet, lack of interaction, and increased teacher workload.

The study of Centeno-Maldonado (2022) was developed to determine the interaction between the virtual platform and meaningful learning for students in a Higher Technological Institute in Lima. For the research, a quantitative approach with a correlational scope was used. A bibliography and an experimental design supported it. For this purpose, a sample of 39 students was taken, and data was collected through several questionnaires. The results showed that 71% of the respondents believe that virtual platforms are used inappropriately, achieving low levels of significant learning (74.4%).

In the study of Fernández-Villacrés, Vivanco-Garzón and Arcos-Naranjo (2022), the design of a technological implementation is presented, which was built to contribute to the digital transformation for the operational management of the department of UNIANDES University. The implementation was evaluated through a quantitative, descriptive, exploratory approach, using analytical-synthetic and inductive-deductive methods. Furthermore, a sample of 139 people was taken using a questionnaire as an instrument. The results showed that 87% of the respondents believe using a digital transformation plan will contribute to optimal operational management.

2. Methodology

For the statistical evaluation of the digital transformation process at the State Polytechnic University of Carchi (UPEC) and its incidence in reducing the use of paper by teaching and administrative staff, a

survey was designed consisting of 18 opinion variables integrating two factors, three categorical variables and two numerical variables to measure the time in which each respondent carried out their daily activities before and after the implementation of digital tools in the institution. The digital tools implemented by the ICT department in recent years were implemented according to the staff's needs and the institution's technological capabilities. The digital tools implemented were:

- Approval certificate issuance module
- Annual operating plan (POA) upload module
- Digital syllabus module
- Power BI data analysis platform
- Document management platform (QUIPUX)
- Telematic voting election system
- Institutional portafolio
- Question banks and virtual learning objects modules
- Work attendance and weekly activities registration modules

In this way, the instrument was designed to indirectly, but generally, assess the perception of improvement in the performance of the tasks that staff perform in the institution through the use of these digital tools. For this purpose, the instrument included a factor called Digital Transformation, which consisted of six questions, as detailed in Table 1.

Digital transformation factor	
Code	**Question**
*p*1	Do you consider that the processes in your dependency have become easier due to the implementation of computer systems in the institution?
*p*2	Do you consider that the execution times of the processes in your dependency have become faster due to the implementation of computer systems in the institution?
*p*3	Do you consider that the number of steps required to carry out a task has decreased due to the implementation of computer systems in the institution?
*p*4	Do you consider that the productivity in the execution of your work has increased due to the implementation of computer systems in the institution?
*p*5	Do you consider that the frequency with which errors occur when carrying out your daily work has decreased due to the implementation of computer systems in the institution?
*p*6	Do you consider that having a computer system makes it easier to demonstrate the execution of your work activities?

Table 1. Questions formulated for the factor digital transformation experienced by the institution's staff

Similarly, a factor was formulated to measure the perception of reduced use of paper, as evidenced by the staff working in the institution. For this, 12 opinion questions were formulated using the 7-level Likert ordinal scale. The variables proposed for measuring this factor are presented in Table 2.

In addition, three categorical variables were added to the instrument to categorize the institution's staff and perform hypothesis contrasts between the groups that determine the categorical variables. The categorical variables selected were: position, number of years of service, and tasks performed using ICT. The categorical variable position was designed to identify within the sample the teaching and administrative staff of the institution who perform different tasks through the implemented computer tools. The intention of including this variable was to identify the difference in the incidence that ICTs have had for the two groups of personnel and to assess the importance of these implementations in each case. In addition, the variable "years of service" was implemented to visualize the incidence of implementations carried out in personnel of different ages. Similarly, the variable "tasks performed by the staff using ICT" allowed us to assess the impact and reception of each implementation on the staff using it.

Paper use reduction factor	
Code	**Question**
*p*7	Do you consider that the institution has an appropriate program for collecting paper for recycling?
*p*8	Do you consider that the containers for recycled paper are correctly located in your work area?
*p*9	Do you consider your entity's staff fully informed about the recycling system?
*p*10	Do you consider that the garbage and recycling containers are properly identified?
*p*11	Do you consider that the recycling paper is duly delivered to those in charge of managing this waste?
*p*12	Do you consider that the signage in the institution is clear enough to guide the recycling of waste paper?
*p*13	Do you think that the amount of paper used has been reduced thanks to the digital processes implemented at the university?
*p*14	Do you consider digital documents to have the same or similar validity as physical documents?
*p*15	Do you consider it important for the university to implement more digital processes to avoid paper consumption?
*p*16	Do you consider running a digital document repository easier and more reliable than a physical document repository?
*p*17	Do you consider that digital document repositories facilitate accessibility to documents (in the cloud) from anywhere?
*p*18	Do you consider that the consumption of paper implies a cost that can be significantly reduced thanks to digital documentation?

Table 2. Questions formulated for the factor paper use reduction evidenced by the institution's staff

For the statistical analysis and extraction of significant information from the instrument, it was taken into account that the initial results compiled in the instrument lacked initial validity and could contain irregular observations that could affect the extraction and interpretation of results. For these reasons, Mahalanobis distances were chosen as the data treatment technique, Confirmatory Factor Analysis (CFA) as the validation technique, and Kruskal-Wallis and Wilcoxon as the tests for differences for the weighted scores obtained by CFA.

2.1. Mahalanobis Distances

The database compiled for any investigation is susceptible to containing missing data and outliers, so it is recommended that any statistical analysis begin with the application of a data analysis protocol. One of the most commonly used data processing techniques for multivariate samples is Mahalanobis distances. Mahalanobis distances allowed us to measure the number of standard deviations an observation is from the mean in a distribution. Since outliers do not behave similarly to common observations, this measure can be used to detect outlier observations. Geometrically, the Euclidean distance is the shortest distance between two points. However, it does not take into account the correlation between highly correlated variables. The Mahalanobis distance differs from the Euclidean distance because it takes into account the correlation between variables (Ghorbani, 2019; Jácome-Ortega et al., 2020). This scale-invariant metric obtains a measure for the distance between a point $x \in \mathbb{R}^p$ generated by a $fx(.)$, p-variated probability distribution, and the mean $\mu = E(X)$ of the distribution. Assuming that the distribution $fx(.)$ has second-order finite moments, the covariance matrix can be defined as $\sum = E(X - \mu)$. Thus, Mahalanobis distances are defined as:

$$D(\boldsymbol{X}, \mu) = \sqrt{(\boldsymbol{X} - \mu)^T \Sigma^{-1} (\boldsymbol{X} - \mu)}. \quad (1)$$

2.2. Confirmatory Factor Analysis

Once the data processing is complete, an instrument composed of ordinal observations must be validated to select a set of variables that correctly explains the factors that make it up, thereby providing validity and reliability. Confirmatory factor analysis is a particularly attractive technique for analyzing ordinal variables, in which the responses of a dimensional vector of $p \times 1$ observable random variables are examined to explain one or more unobserved variables, called factors η. In this way, the saturation of each item

proposed to explain different aspects of the unobserved latent variable is evaluated and estimated. In this formulation, there is a vector of observed responses Y_i that are predicted by the unobserved latent variable ξ, through the model:

$$\boldsymbol{Y} = \boldsymbol{\Lambda}\,\xi + \epsilon, \tag{2}$$

Where Y is the dimension vector of $p \times 1$ observed random variables, ξ are the unobserved latent variables, and Λ is a matrix with $p \times k$ dimensions with k equal to the number of unobserved latent variables. Also, as Y is constituted by a set of variables that imperfectly explain ξ the model considers the error $\in$. The model is typically solved by maximum likelihood (ML) estimation, which is generated by iterative minimization of the fit function:

$$\begin{aligned} F_{ML} &= ln|\boldsymbol{\Lambda\Omega\Lambda'} + \boldsymbol{I} - diag(\boldsymbol{\Lambda\Omega\Lambda'})| \\ &+ tr\big(\boldsymbol{R}(\boldsymbol{\Lambda\Omega\Lambda'} + \boldsymbol{I} - -diag(\boldsymbol{\Lambda\Omega\Lambda'})^{-1})\big) - \ln(\boldsymbol{R}) - p, \end{aligned} \tag{3}$$

Where $\Lambda\Omega\Lambda'$ is the variance-covariance matrix involved in the proposed factor analysis model, and R is the observed variance-covariance matrix. This way, the model parameters are estimated by minimizing the distance between the variance-covariance implied in the model and the observed one (Rosseel, 2012; Yang-Wallentin, Jöreskog & Luo, 2010).

2.3. Kruskal-Wallis Test

The results obtained by cleaning the data and validating the construct through CFA guarantee that a data sample is available that is not modified by the influence of outliers and that is composed only of a set of variables that correctly explain the factors of interest. The information obtained by solving the CFA parameters allows a correct assessment of the values obtained in each observation for the unobserved latent variables (factors). Since these data come from ordinal variables, a nonparametric technique must be used for comparison. The Kruskal-Wallis test is a nonparametric alternative to one-way ANOVA, which assumes that the observations in each sample group come from a sample with the same distribution. Thus, the null hypothesis configured for this test is:

$$H_0: \eta_1 = \eta_2 = \cdots = \eta_k, \tag{4}$$

Where η_i is the median of the ith group defined by the categorical variable in the sample. In this case, the null hypothesis is equivalent to "*H_0: the samples come from identical populations*". We define n as the total number of observations $n = \sum_{i=1}^{k} n_i$ where n_i represents the sample size of each group i = 1,2, …, k and k represent the number of groups to be compared. Ranks are obtained for each observation in ascending or descending order of magnitude if there are ties. Thus, $R(X_{ij})$ represents the rank assigned to the j-th observation of the i-th group, X_{ij} and R_i represent the sum of ranks assigned to the i-th group $R_i \sum_{i=1}^{ni} R(X_{ij})$, for i = 1,2, …, k. In this way, the static test T is defined as:

$$T = \frac{1}{S^2}\left(\sum_{i=1}^{k}\frac{R_i^2}{n_i} - \frac{n(n+2)^2}{4}\right), \tag{5}$$

where:

$$S^2 = \frac{1}{n-1}\left(\sum_{allrank} R\big(X_{ij}\big)^2 - \frac{n(n-1)^2}{2}\right). \tag{6}$$

If there are no ties, S^2 is simplified to the expression $n(n + 1)/12$ and the statistical test is reduced to Equation 7:

$$T = \frac{12}{n(n+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(n+1). \quad (7)$$

Under the null hypothesis H_0 and the previously defined assumption, T is asymptotically distributed to the chi-square distribution with k – 1 degrees of freedom $T \sim \chi^2_{k-1}$ (Lehmann, 2006; Nwobi & Akanno, 2021).

3. Results

The sample collected for this study consisted of 203 observations of the university's teaching and administrative staff, with the participation of staff from the following departments: Rector's Office, Vice Rector's Office, Postgraduate Center, Academic Directorates (Academic, Relations with Society, Integration and University Welfare), Administrative Directorates (Administration, Infrastructure, Planning, Finance, ICT), Faculty of Agricultural Industries and Environmental Sciences, Faculty of International Trade, Integration, Administration and Economics, Library, General Secretariat, General Secretariat, Commissions (Evaluation, Publications, International Relations, REDEC), Headquarters (Communications, Acquisitions, Warehouse, Human Resources, Laboratories, Services), Academic Support Centers (Languages, Physical and Aesthetic Culture, ICT, Entrepreneurial Ecosystem), Observatories (Binational Border), Experimental Centers, UPEC Creative EP, Security and Cleaning. In addition, it has been considered to include personnel who carry out each of the activities in which the Information and Communication Technologies (ICT) Department has contributed to the digital transformation of the activities carried out by the personnel. The tasks in which the ICT management has made improvements are Issuance of authorization certificates, loading of the annual operating plan (POA), registration and monitoring of the curriculum, Power BI data analysis, QUIPUX document management, institutional portfolio, creation of question banks and/or virtual learning objects, and recording of work attendance and weekly activities.

The designed instrument was composed of 3 categorical variables: position (teacher or administrative staff), number of years of work (1 to 5, 6 to 10, more than 10), and daily tasks performed using ICT. Also, two numerical variables were included to collect and contrast the time staff took before and after implementing ICT digital transformation. In addition, 18 opinion questions generated from a factorial structure were included, consisting of 6 questions for the digital transformation factor and 12 questions for the paper use factor. The descriptive statistics of the numerical and ordinal variables that made up the sample are presented in Table 1.

Variable	Min-before	Min-after	*p*1	*p*2	*p*3	*p*4	*p*5	*p*6	*p*7	*p*8
Min.	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1st Qu.	10.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00	3.00
Median	30.00	10.00	6.00	6.00	6.00	6.00	6.00	6.00	5.00	5.00
mean	109.70	43.95	5.66	5.67	5.32	5.62	5.32	5.85	4.31	4.31
3rd Qu.	60.00	30.00	7.00	7.00	7.00	7.00	6.00	7.00	6.00	6.00
Max.	2000.00	480.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Std . deviation	327.60	98.67	1.61	1.53	1.64	1.63	1.56	1.59	1.75	1.89

Variable	*p*9	*p*10	*p*11	*p*12	*p*13	*p*14	*p*15	*p*16	*p*17	*p*18
Min.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1st Qu.	3.00	4.00	2.00	3.00	4.00	6.00	6.00	6.00	6.00	6.00
Median	4.00	5.00	4.00	5.00	5.00	7.00	7.00	7.00	7.00	7.00
mean	4.17	4.93	4.09	4.28	5.01	6.09	6.44	6.16	6.43	6.43
3rd Qu.	6.00	6.00	6.00	6.00	7.00	7.00	7.00	7.00	7.00	7.00
Max.	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Std . deviation	1.84	1.83	1.94	1.89	1.81	1.43	1.03	1.32	1.03	1.09

Table 1. Descriptive statistics of the numerical and ordinal variables for the collected sample

3.1. Data Treatment

The instrument included a constraint on the completion of each item during the collection of each observation, so there were no missing values. In addition, the presence of atypical observations in the sample was checked using Mahalanobis distances. For this, the Mahalanobis distances were calculated for each observation with respect to the centroid of the data so that a cut-off value of 42.3124 was established by the χ^2 distribution for a 99.9% interval with the same number of degrees of freedom of the sample. In this way, 8 atypical observations were detected and removed from the database, leaving a total of 195 observations.

3.2. Validity and Reliability of the Instrument

Confirmatory Factor Analysis (CFA) was chosen as the validation technique for the instrument, as it allows the evaluation of the validity and reliability of the instrument while at the same time allowing the extraction of the saturations and coefficients of determination of each item in the factorial structure. Since CFA is a parametric technique, the analysis began with verifying the parametric assumptions of additivity, multivariate normality, linearity, homogeneity and homoscedasticity. For the additivity assumption, the multivariate correlation matrix was obtained for each possible pair of questions. The correlation matrix of the instrument's ordinal variables is shown in Figure 1.

As can be seen in Figure 1, all the pairs of questions in the instrument reached acceptable levels of correlation, and it was evidenced that none of the pairs was perfectly correlated; therefore, the additivity assumption was accepted.

For the assumptions of normality, linearity, homogeneity and homoscedasticity, the fake regression analysis was used, which allows for comparing the sample quantiles with the theoretical quantiles of the χ^2 distribution, in addition to estimating their indices through a regression model. The assumptions of normality, linearity, homogeneity and homoscedasticity were checked using the histogram, QQ plot and scatter plot shown in Figure 2.

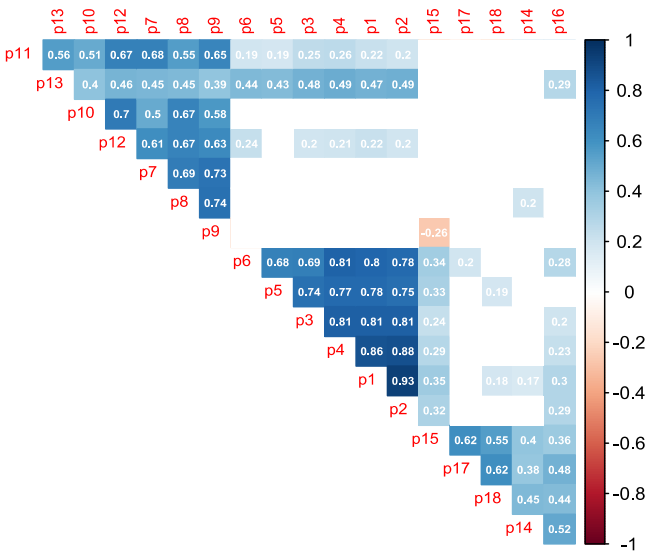

Figure 1. Additivity assumption – Correlation matrix for each possible pair of questions

As can be seen, Figure 2a shows the histogram of the fitted values of the regression using the quantiles of the distribution χ^2 as the response variable and the questions from the database as predictors. First, these fitted values were standardized, and their histogram was obtained. As shown in Figure 2a, the distribution observed in the histogram is similar to the normal distribution, so the assumption of normality was accepted. Then, the quantiles obtained from the multivariate sample were plotted based on the theoretical

quantiles of the distribution χ^2. As observed in Figure 2b, these were similar to a straight line with slope one, so the assumption of linearity was accepted. Figure 2c shows the scatter-plot of the standardized quantiles with respect to those adjusted by regression, where it can be seen that they are similarly distributed over the four quadrants in the interval from -2 to 2. In addition, no pre-established patterns or vertical groupings were observed, so the homogeneity and homoscedasticity assumptions were accepted.

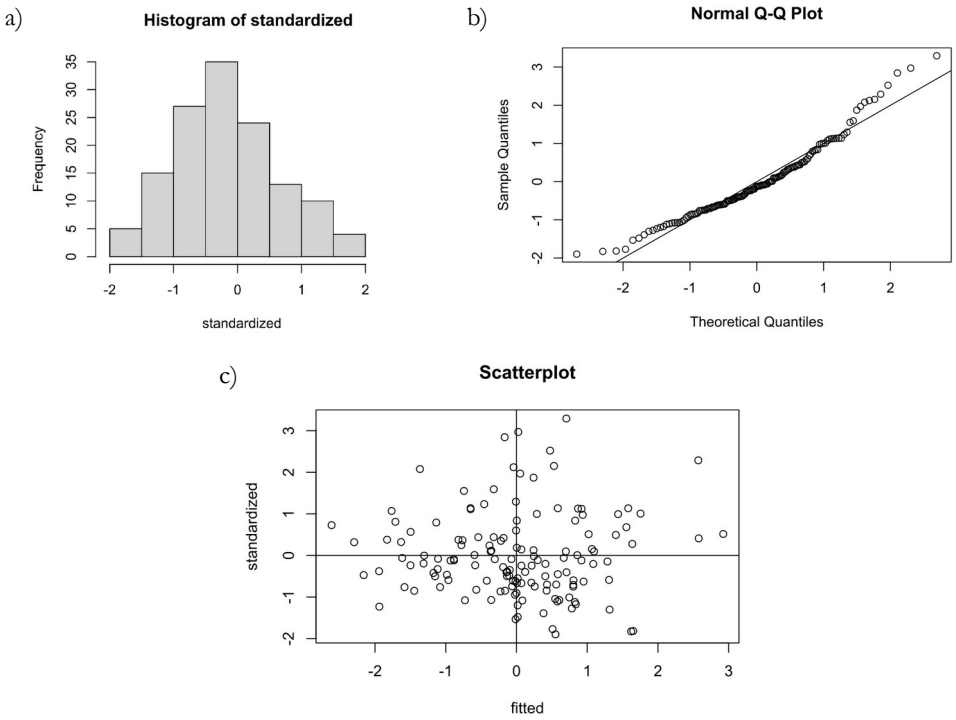

Figure 2. Parametric assumptions, a) histogram, b) quantile plot (QQ Plot), c) dispersion plot (Scatter-plot)

Once the parametric assumptions were verified, it was concluded that the multivariate sample met the requirements, so the Confirmatory Factor Analysis was carried out using the libraries *lavaan* and *semPlot*. The results obtained are presented in Figure 3 and Table 2.

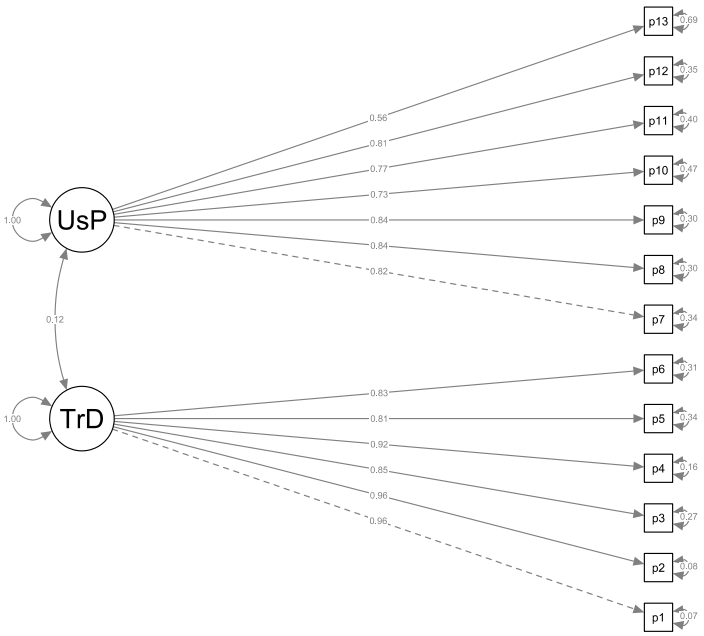

Figure 3. Path diagram (path-diagram) Exploratory Factor Analysis

npar	*fmin*	*chisq*	*df*	*pvalue*
27.000	0.751	211,868	64,000	0,000
baseline.chisq	*baseline.df*	*baseline.pvalue*	***cfi***	***tli***
1758,795	78,000	0,000	**0.912**	**0.900**
mnfi	*rfi*	*nfi*	*pnfi*	*ifi*
0.90 0	0.853	0.880	0.722	0.913
ntotal	*bic*2	***rmsea***	*rmsea.ci.lower*	*rmsea.ci.upper*
141,000	5595.085	**0.047**	0.038	0.054
rmsea.ci.level	*rmsea.pvalue*	*rmsea.close.h*0	*rmsea.notclose.pv*	*rmsea.notclose.h*0
0.900	0,000	0.050	1,000	0.080
rmr	*rmr.nomean*	***srmr***	*srmr.bentler*	*srmr.bentler.nom*
0.053	0.053	**0.048**	0.049	0.049
crmr	*crmr.nomean*	*srmr.mplus*	*srmr.mplus.nom*	*cn.*05
0.141	0.141	0.131	0.131	56,687
*cn.*01	*gfi*	*agfi*	*pgfi*	*mfi*
63,037	0.814	0.736	0.573	0.592

Table 3. CFA goodness-of-fit indices

As can be seen in Figure 3 and Table 2, the instrument was modified and validated for the CFA, for which questions 14, 15, 16, 17 and 18, whose loadings did not reach the minimum contribution of 0.5, were eliminated, so that the final instrument consisted of 13 questions, 6 for the digital transformation factor and 7 for the paper use factor. In this way, as can be seen in Figure 3, all the loadings of the questions concerning their factor reached a value greater than 0.5, while the interfactorial correlation maintained a low value of 0.12, confirming that the factors were correctly constructed; therefore, no evidence of invalidity was evidenced in the instrument. In addition, Table 2 presents the goodness of fit indices where it can be highlighted that the CFI (Comparative Fit Index), the TLI (Tucker & Lewis Index), and the NNFI (Not-Normed fit Index) reached values of 0.912, 0.900, and 0.900 respectively, which are higher than 0.9. Similarly, the RMSEA (Root mean squared error of approximation) and the SRMR (Standardized Root Mean-Square) reached values of 0.047 and 0.048, respectively, so it was concluded that the instrument is valid and reliable. In addition, the CFA provides among its outputs the determination coefficients r^2 for the model integrated by each question as a regressor of its factor, representing the variance that each question can explain for the variance of its respective factor. The determination coefficients of each question in each factor are shown in Figure 4.

As seen in Figure 4, each question selected for the final model contributed with different intensities to its respective factor. In this way, question one, "Do you consider that the processes in your department have become easier due to the implementation of computer systems?" was the most influential factor for the digital transformation. In contrast, question five, "Do you consider that the frequency with which errors occur when carrying out your daily work has decreased due to the implementation of computer systems?" had less contribution to this factor. Similarly, in the paper use factor, it was obtained that question nine, "Do you consider that the personnel of your entity is duly informed about the recycling system?" was the most influential. In contrast, question 13, "Do you think that paper consumption implies a cost that can be significantly reduced thanks to digital documentation?" was the lowest contribution for its respective factor. Using the estimated coefficients of determination, an adequate weighted score was obtained according to the statistics for the digital transformation and paper use reduction factors. The descriptive statistics for each factor are presented in Table 4 and Figure 5.

As can be seen in Figure 5 and Table 4, descriptively, when looking at the scores obtained for the digital transformation and paper use reduction factors, the median percentages obtained were 84.67 and 65.81, respectively. This indicates that the university community has received the digital transformation integrations and modules implemented by the ICT department well. However, it can also be seen that the

paper use reduction factor has reached a high score of more than half of the scale but lower than that visualized for digital transformation, suggesting that there is still work to be done regarding this factor.

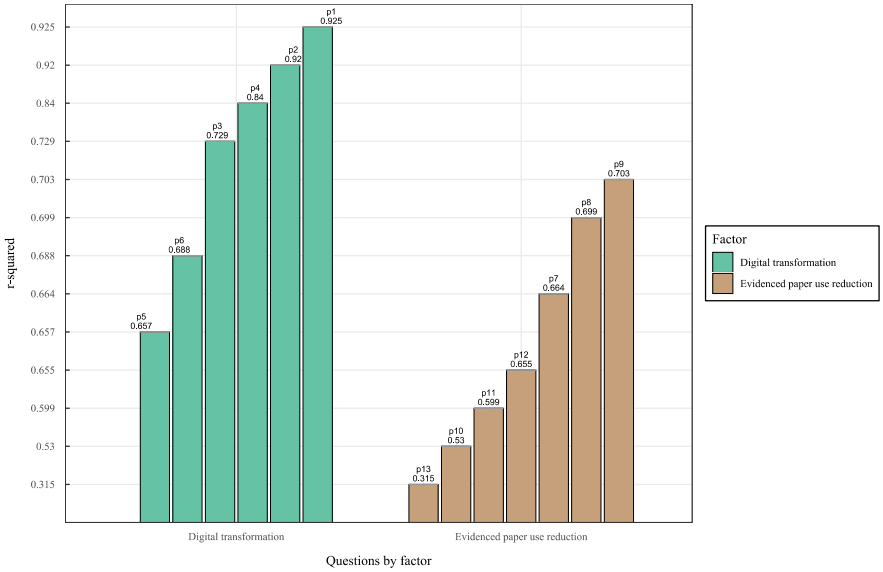

Figure 4. Coefficients of determination r^2 obtained through the CFA

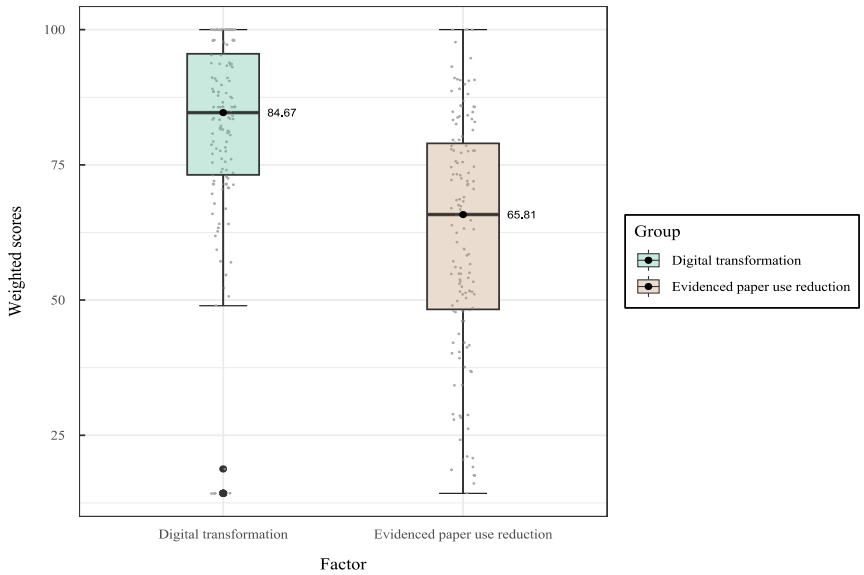

Figure 5. Box plots for each factor weighted scores

Variable	Digital transformation	Evidenced paper use reduction
Min.	14.29	14.29
1st Qu.	73.17	48.27
Median	84.67	65.81
mean	80.98	62.36
3rd Qu.	95.53	78.98
Max.	100.00	100.00
Std . deviation	19.67	21.62

Table 4. Descriptive statistics of the numerical and ordinal variables for the sample

3.3. Tests for Differences

Then, using the correctly weighted scores based on the validated instrument, all the possible tests for differences were performed using the categorical variables: position, years of service, and activities performed by the staff using ICT. The analysis began by comparing the scores of the digital transformation factor with the position of the personnel to whom the instrument was applied, for which the Mann-Whitney U test was used since the categorical variable describes only two groups. The results of the test for differences are presented in Table 5 and Figure 6.

U Man-Whitney test with continuity correction			
W	2046.5	*p – value*	0.04533
95 percent confidence interval			
Min.	–1.000803e+01	Max.	6.905136e–05

Table 5. Mann-Whitney U test for digital transformation scores for the categorical variable position

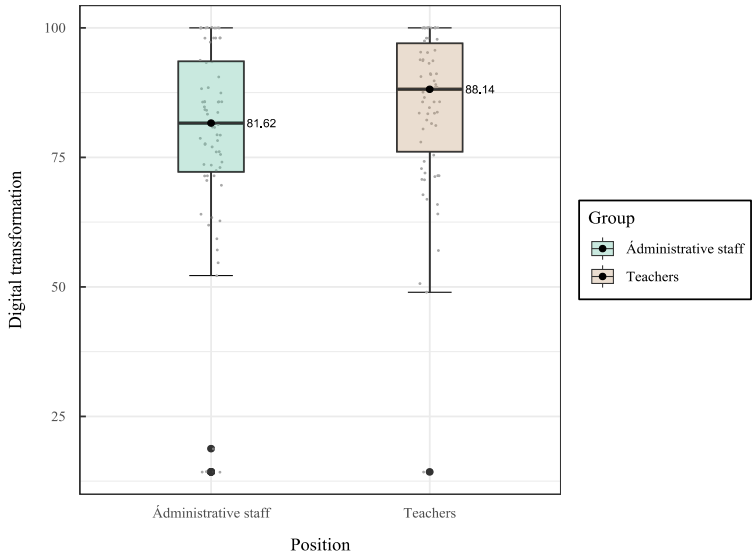

Figure 6. Box-plots and median differences for the digital transformation scores among administrative staff and teachers

As seen in Figure 7, the median scores for digital transformation and paper use reduction for the groups defined by the categorical variables years of service and daily activities carried out using ICT are quite close. Therefore, the significance level was not reached when carrying out the tests of differences. However, descriptively, it can be seen that the personnel who worked between 5 to 10 years in the institution was the one that evidenced the highest incidence of digital transformation, while the personnel with the least number of years of service (5 to 10 years), was the one that has assigned the highest score for paper used reduction in the institution. Additionally, the personnel who use the digital syllabus upload service considered the effect of digital transformation experienced to be greater, while the personnel who use the annual operating plan (POA) upload is the one who valued the paper use reduction with the highest score. Also, as can be seen in Figure 7e, the administrative staff valued the experienced paper use reduction in the institution in a better way due to the implementations carried out by the ICT's direction.

As can be seen in Table 5, the Mann-Whitney U test reached the level of significance, so it was concluded that the perception of digital transformation experienced by teachers presented a significant difference with respect to administrative staff, with a p-value of 0.04533, and as can be seen in Figure 6, teachers valued this effect with a higher score, which suggests that the changes implemented have had a significantly greater impact on the teaching staff.

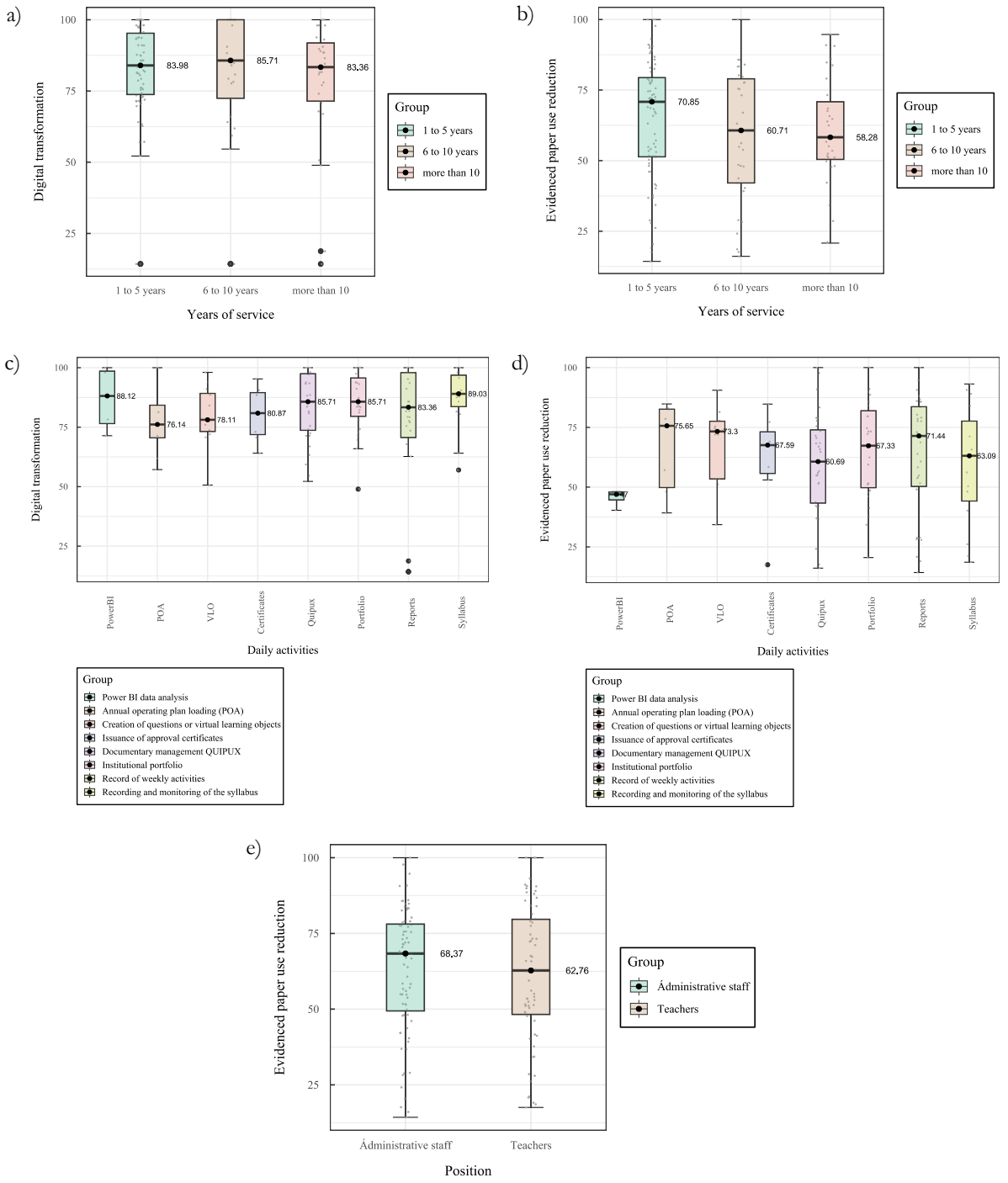

Figure 7. Box plots and median differences for the digital transformation and paper use reduction scores among the categoric variables

In the same way, the Mann-Whitney U and Kruskal-Wallis tests were executed for the other categorical variables and the paper use reduction factor. However, the significance level was reached in none of these tests, so these results are presented descriptively in Figure 7.

Finally, through the numeric variables gathered for the time that the staff spent in their daily activities before the implementation of ICTs, and after its implementation, a differences test was carried out to find out if the time reduction experienced in the performance of daily tasks was significant. For this, the Wilcoxon test with continuity correction was used for the paired samples minutes before and after. The results are presented in Table 6 and Figure 8.

Wilcoxon signed-rank test with continuity correction			
V	6589.5	*p – value*	2.2e–16
95 percent confidence interval			
Min.	17.49995	Max.	27.49991

Table 5. Wilcoxon signed-rank test with continuity correction for the times before and after the digital transformation

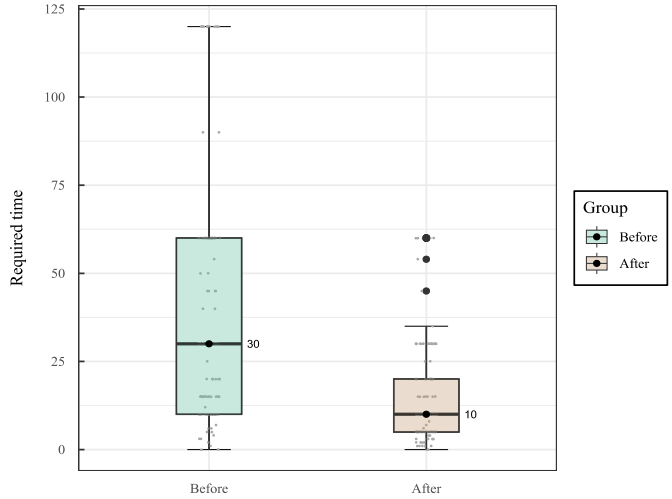

Figure 8. Box plots and median differences for the required times before and after digital transformation

As seen in Table 5, the times the teacher and administrative staff used to carry out their activities before and after the digital implementations showed a significant difference. As seen in Figure 8, the time the staff spends after the digital implementations is significantly less than it used to take before them, presenting a p-value of 2.2e-16. Figure 9 shows the decrease in time experienced by the teaching and administrative staff before and after the digital implementations in the institution.

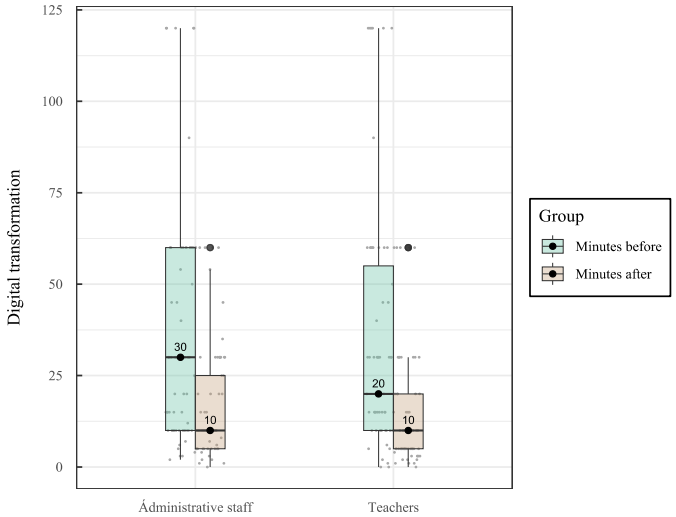

Figure 9. Box plots and median differences for the required times spent by teachers and administrative staff in performing their work before and after digital transformation

4. Discussion

This study presents a significant contribution to the body of knowledge in the field of environmental sustainability in the university context. Through an innovative methodology and a rigorous analytical

approach, this research addresses the problem of excessive paper consumption in higher education institutions and proposes effective strategies for its mitigation. Compared to previous studies in this field, such as (Pérez-Ruiz, 2019), which focused on the carbon footprint of a specific faculty, and (Maldonado, 2006), which examined the reduction and recycling of municipal solid waste in a higher education institution, this work is distinguished by its exclusive focus on reducing paper use. While (Pérez-Ruiz, 2019) and (Armijo-de-Vega, Ojeda-Benítez, Ramírez-Barreto & Quintanilla-Montoya, 2006) provided comprehensive analyses of greenhouse gas emissions and overall waste generation, respectively, this study focuses specifically on paper as a critical component of university waste and its environmental impact.

The methodology employed in this study is remarkable for its rigor and precision. Unlike (Royero, 2006), which analyzed the importance of R&D networks and the use of ICTs in Latin American universities, this work adopts a quantitative approach to evaluate the reduction of paper use. Advanced statistical techniques were implemented to analyze the data collected, allowing a detailed assessment of paper consumption trends and the effectiveness of the reduction measures implemented. This methodological approach provides a solid basis for the generation of specific and evidence-based recommendations for sustainable paper management in universities. One of the main contributions of this study is the identification of effective strategies for reducing paper consumption in the university context. Through a thorough analysis of current practices and the implementation of innovative measures, a significant reduction in paper consumption was achieved, which in turn contributes to the reduction of the institution's environmental footprint. These strategies range from digitizing administrative and academic processes to promoting a culture of environmental awareness among the university community.

In contrast to previous studies, such as that of Arias-Corrales and Chao-Chao (2023), which focused on methodological adaptation and the use of ICT in language teaching during the COVID-19 pandemic, this paper addresses paper management from a comprehensive and sustainable perspective. It addresses not only environmental, but also economic and social aspects, aligning paper reduction practices with the institution's sustainable development goals. In this way, our study represents a significant advance in research on sustainable university management, particularly in the area of paper reduction. Through a rigorous methodology and detailed analytical approach, a deeper understanding of the dynamics of paper consumption in universities has been achieved and effective strategies for its reduction have been proposed. The implications of this work are highly relevant to the promotion of sustainable practices in the higher education context and can serve as a model for other institutions seeking to reduce their environmental impact.

Summarizing, this study has both similarities and differences with previous studies such as (Armijo-de-Vega et al., 2006; Maldonado, 2006; Pérez-Ruiz, 2019). This study emphasizes the environmental impact of university activities, specifically focusing on the reduction of paper use. However, it differs in that it focuses exclusively on paper, while the others address broader sustainability issues, including carbon footprint and waste management. Similar to (Arias-Corrales & Chao-Chao, 2023; Royero, 2006), this study acknowledges the role of technology in sustainable practices, but uniquely combines this with a quantitative approach to measure paper use reduction. The methodology used in this study is notable for its statistical rigor, which sets it apart from the more qualitative or mixed methods approaches found in the other articles. Overall, this study contributes to the field by providing a focused analysis of paper reduction strategies in the context of sustainable university management.

It is worth mentioning that the digital transformation experienced by the teaching staff and the reduction in the use of paper reached very high scores, so it is concluded that the digital implementations made by the ICTs direction have been carried out satisfactorily in the institution and are widely accepted by the users who are teachers and administrative staff. In addition, when comparing the scores of digital transformation between the teaching and administrative staff, significant differences were identified, suggesting that the digital implementations promoted by the institution have had a significantly higher acceptance among the teaching staff than among the administrative staff. Similarly, when comparing the execution times of the tasks related to the modules and computer systems implemented in the institution,

significant differences were identified between the times taken by the staff before and the current ones. In this way, it was possible to show that the time that the staff currently takes to carry out their daily activities is significantly less than the time it took before the digital implementations were made in the university, which shows a correct implementation and contribution of the technology implemented in the institution. Finally, it was possible to observe in a descriptive way that the implementations carried out in each module and system reached high approval scores by the teaching and administrative staff, which proves the approval and reception that these tools have had even among personnel of different ages and periods of service.

5. Conclusions

This study conducted an in-depth analysis of the perception of digital transformation and paper reduction in a higher education institution. For this purpose, numerical, categorical, and opinion information was collected from the institution's faculty and administrative staff, and a statistical protocol was proposed for analyzing and extracting inferential information from the sample. The proposed statistical protocol consisted of a combination of statistical techniques: Malanobis distances as a data treatment technique, confirmatory factor analysis as a validation technique, and the Kruskal-Wallis and Wilcoxon tests as difference analysis tests. The results showed that the information in the initial sample before the validation process differs significantly from that obtained from a treated and validated database. Therefore, this study demonstrated the importance of applying an appropriate statistical protocol prior to analysis or decision-making for technological implementations in higher education institutions. In addition, this study demonstrated the power of CFA to obtain models from ordinal data that allow a better description of latent variables that are not directly observed, such as digital transformation and paper use reduction, which, as demonstrated in this study, can be better explained by a broad set of opinion variables than by asking direct Boolean questions.

This study provides empirical evidence of a significant improvement in task completion times and higher acceptance of digital initiatives among faculty compared to administrators. This differential acceptance underscores the nuanced impact of digital transformation on different institutional roles. The research concluded that the digital strategies and digital tools developed and implemented were successfully integrated and well received, contributing significantly to the institution's sustainability goals. Thus, in addition to highlighting the practical benefits of digital transformation in higher education, this study sets a precedent for the adoption of similar sustainability practices in other institutions.

Declaration of Conflicting Interests

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