

ECONOSCITECH INTEGRATION

ISSUE
8

INTERNATIONAL SCIENTIFIC
ELECTRONIC JOURNAL



**TASHKENT STATE
UNIVERSITY OF ECONOMICS**



**American University
of Technology**

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ISSN: 3060-5075



Acceptance of articles

PUBLISHED EVERY MONTHLY



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INTERNATIONAL
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2026

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THE SCIENTIFIC-POPULAR
ELECTRONIC JOURNAL
"ECONOSCITECH-INTEGRATION"
HAS BEEN REGISTERED UNDER
THE NUMBER C-5669651 BY THE
AGENCY FOR INFORMATION AND
MASS COMMUNICATIONS (AOKA)
OF THE REPUBLIC OF UZBEKISTAN,
EFFECTIVE FROM OCTOBER 9, 2024.

In accordance with Resolution No. 384/6 dated April 10, 2026, issued by the Presidium of the Supreme Attestation Commission under the Ministry of Higher Education, Science and Innovation of the Republic of Uzbekistan, this journal is included in the list of recommended international scientific publications for publishing the primary research findings of doctoral dissertations in the field of Economic Sciences.

Partners: Tashkent State University of Economics / American University of Technology in Tashkent (AUT)

Electronic publication. Issue 8. 374 pages.
Approved for publication in August 2026.

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LEVERAGING INNOVATIVE TECHNOLOGIES ON DEVELOPING THE MANAGEMENT SYSTEM OF PRIVATE SCHOOLS METHODS USED: QUADRATIC REGRESSION, CORRELATION

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Abstract. The management effects of digitalization are associated with practical benefits such as reduced paper use, lower administrative costs, fewer delays, and more organized school operations. The adoption of innovative technologies can contribute to improving school management by strengthening coordination, communication, monitoring, and decision-making processes, although these outcomes largely depend on the level of digital readiness within the institution.

The aim of this study is to examine the relationship between innovative technology adoption and the development of the management system of private schools, with particular attention to potential nonlinear effects. Using survey data collected from staff members of selected private schools during 2024–2025, the study applies correlation analysis and quadratic regression to assess the relationship between technology adoption and management efficiency.

The findings indicate that private schools are more likely to adopt technologies related to administrative and management functions than to teaching activities. The correlation analysis shows that technology adoption is more strongly associated with management-related processes, particularly communication, coordination, and monitoring. The quadratic regression results indicate that technology adoption has a positive and statistically significant association with coordination and management efficiency, while the squared term is negative but statistically insignificant. This suggests that the evidence for a nonlinear effect is limited, although the estimated pattern may indicate diminishing marginal benefits at higher levels of technology adoption.

The study concludes that the effective use of innovative technologies in private-school management depends on staff support, the administrative relevance of the technologies introduced, and the availability of integrated digital platforms that support management processes. The findings suggest that digital coordination may represent one of the main channels through which technology adoption contributes to the development of management systems in private schools.

Keywords: innovative technologies, private schools, school management, technology adoption, management efficiency, digital readiness, quadratic regression.

Аннотация. Управленческий эффект цифровизации связан с такими практическими преимуществами, как сокращение использования бумажных документов, снижение административных расходов, уменьшение задержек и более организованное функционирование школы. Внедрение инновационных технологий может способствовать совершенствованию управления школой за счёт улучшения координации, коммуникации, мониторинга и процессов принятия решений, однако получаемые результаты во многом зависят от уровня цифровой готовности образовательного учреждения.

Целью данного исследования является изучение взаимосвязи между внедрением инновационных технологий и развитием системы управления частными школами с особым вниманием к возможным нелинейным эффектам. На основе данных опроса сотрудников отдельных частных школ, собранных в 2024–2025 годах, в исследовании применяются корреляционный анализ и квадратичная регрессия для оценки взаимосвязи между внедрением технологий и эффективностью управления.

Результаты показывают, что частные школы в большей степени склонны внедрять технологии, связанные с административными и управленческими функциями, чем технологии, непосредственно относящиеся к учебному процессу. Корреляционный анализ показывает, что внедрение технологий в большей степени связано с управленческими процессами, в частности с коммуникацией,

координацией и мониторингом. Результаты квадратичной регрессии свидетельствуют о положительной и статистически значимой связи между внедрением технологий, координацией и эффективностью управления, тогда как квадратичный член имеет отрицательный, но статистически незначимый коэффициент. Это указывает на ограниченность доказательств наличия нелинейного эффекта, хотя выявленная тенденция может свидетельствовать о возможном снижении предельной отдачи при более высоком уровне внедрения технологий.

В исследовании делается вывод о том, что эффективное использование инновационных технологий в управлении частными школами зависит от поддержки со стороны сотрудников, соответствия внедряемых технологий административным задачам, а также наличия интегрированных цифровых платформ, поддерживающих управленческие процессы. Полученные результаты позволяют предположить, что цифровая координация может быть одним из основных каналов, посредством которых внедрение технологий способствует развитию системы управления частными школами.

Ключевые слова: инновационные технологии, частные школы, управление школой, внедрение технологий, эффективность управления, цифровая готовность, квадратичная регрессия.

INTRODUCTION

The integration of digital platforms, management information systems, and other innovative technologies into school administration has become an important factor in improving school management systems [3, 7, 15]. Technologies such as communication platforms, financial systems, and monitoring tools can support the coordination of school activities and administrative decision-making processes [3, 6, 15].

Despite the growing use of digital technologies in schools, their effects on management efficiency remain insufficiently explained. One reason is that digital technologies are used not only for administrative purposes but also for teaching and other classroom activities. Therefore, the effects of technology adoption may differ depending on how and where technologies are applied within the school.

Existing evidence indicates that technology adoption can influence administrative activities, communication, coordination, monitoring, and decision-making. However, relatively few studies have directly examined and tested the relationship between technology adoption and management efficiency, while much of the previous research has focused on public schools [7, 9]. In addition, the effectiveness of technologies may depend on the readiness of the school, staff, management, and infrastructure [7, 10].

Another limitation of the existing literature is that most studies have focused on the linear effects of technology adoption on management or have relied on case-based evidence [4, 11, 13]. This creates a need to examine whether the relationship between technology adoption and management efficiency may also have nonlinear characteristics.

Accordingly, the first objective of this study is to examine the effect of technology adoption on school-level management efficiency. The second objective is to analyze the correlation between technology adoption and selected management outcomes, including communication, coordination, and monitoring. The study aims to contribute to the existing literature by examining how technology adoption is associated with management efficiency under possible nonlinear conditions.

LITERATURE REVIEW

Previous studies have emphasized the role of digital platforms, management information systems, and other innovative technologies in improving school management systems [3, 7, 15]. Researchers have examined the use of communication platforms, financial systems, and monitoring tools as instruments for supporting coordination and administrative decision-making in schools [3, 6, 15].

Mbawala et al. [9] suggested that information systems are important drivers of effective school management. Their study, based on survey data from Tanzania, indicated that information systems can function as management tools and support decision-making processes that contribute to greater administrative efficiency.

Blau and Presser [3] examined the role of technology in schools in relation to e-leadership and data management. Their findings indicate that improvements associated with increased technology use can be supported by effective data management.

Liu et al. [7] and Mahulae and Panjaitan [8] also examined the role of digital technologies in improving school administration and emphasized the importance of effective technology application. Their studies suggest that the effects of technology adoption depend not only on the availability of digital tools but also on how effectively these tools are integrated into administrative processes.

Previous studies have also indicated that technologies used for teaching and other classroom activities may depend on the institutional readiness of schools [7, 10]. This suggests that the effectiveness of technology adoption may be influenced by the readiness of staff, management, and infrastructure.

Case-based studies have also examined the use of information systems as management variables in selected schools [4, 11, 13]. However, these studies do not fully explain the process through which technology adoption is related to management efficiency. In addition, much of the existing research has focused on linear relationships between technology use and management outcomes.

Therefore, there remains a need to examine the relationship between technology adoption and management efficiency using approaches that can capture possible nonlinear effects. Quadratic regression has been used in regression analysis to examine nonlinear relationships [7, 15], making it relevant to the assessment of technology adoption and school management efficiency.

RESEARCH METHODOLOGY

The study employed a quantitative, survey-based approach using primary questionnaire data collected from selected private schools in urban regions during the 2024–2025 period, covering two academic years. The dataset consisted of responses from 300 staff members of selected private schools.

The respondents represented different functional groups within the schools. The sample included 90 respondents from school management, 85 from administrative and finance departments, 75 teaching staff members, and 50 respondents from information technology, monitoring, and support units. Students, parents, and external suppliers were excluded from the sample because the study focused specifically on school staff as direct users of technology in administrative and management processes. The adequacy of the sample was assessed through the distribution of respondents across these categories, as presented in the descriptive statistics in Table 1.

The study focused primarily on technologies used for administrative purposes. Classroom technologies, such as smartboards and learning applications designed exclusively for teaching activities, were distinguished from technologies used in management processes. This distinction was necessary because the research problem concerns the role of technology in improving administrative coordination, communication, and monitoring rather than teaching performance.

The questionnaire instrument classified technology-related items into two main groups: (1) administrative technologies, including digital tools used for coordination, school monitoring, communication, and management; and (2) teaching technologies, including digital tools used exclusively for classroom activities. This classification made it possible to distinguish technologies according to their functional purpose and to compare their use across different types of school activities.

Technology adoption was used as the main explanatory variable. It was measured at the respondent level based on the number of questionnaire items indicating the use of digital platforms, information systems, monitoring tools, and communication applications. In addition, a binary technology-adoption indicator was constructed. It took the value of one when the technology score in the relevant administrative category was greater than or equal to the average score of the corresponding group, indicating active use, and zero otherwise.

The dependent variable was management efficiency as reported by staff in relation to the use of technology in school administration. The management-efficiency measure was based on three key dimensions identified in [7]: communication, coordination, and monitoring (CCM). The management-efficiency score reflected the average reported improvement in administrative activities associated with technology use. Teaching performance was not included as an outcome variable in the study.

The explanatory variables also included respondents' digital readiness, technology type, and adoption status. Digital readiness was treated as a categorical variable distinguishing between low and high readiness levels. Technology type was classified as either administration-related or teaching-related, while adoption status distinguished between active technology use and non-active use.

The collected responses were also classified according to three management functions: communication, coordination, and monitoring, as presented in Table 2. This classification was used to evaluate the relationship between technology adoption and specific management outcomes.

The first stage of data preparation involved screening the questionnaire responses for missing values and applying an exclusion rule as part of the data-cleaning procedure. Following data cleaning, descriptive statistics and a Pearson correlation matrix were examined.

To assess the relationship between technology adoption and management efficiency, the study employed ordinary least squares (OLS) regression. In Model 1, technology adoption was initially introduced as a linear explanatory variable. Subsequently, a quadratic term was added to examine whether the relationship between technology adoption and management efficiency exhibited a nonlinear pattern.

The quadratic specification was selected to test whether the effect of technology adoption changed at higher levels of adoption and whether a turning pattern could be identified. For robustness testing, additional control variables were included because technology adoption may be correlated with digital readiness. The available control variables derived directly from the survey data included staff position, school size, and digital readiness, as presented in Table 3. An interaction control was also introduced to account for differences in the digital readiness of schools.

The empirical analysis therefore consisted of descriptive statistics, Pearson correlation analysis, linear regression, quadratic regression, and robustness checks using the available survey-based control variables.

ANALYSIS AND RESULTS

The descriptive analysis first examined the distribution of respondents across school management, administrative and finance departments, teaching staff, and information technology, monitoring, and support units. The final analytical sample consisted of 300 respondents from selected private schools during 2024–2025.

The analysis distinguished between technologies used for administrative purposes and those used primarily for teaching activities. Administrative technologies included digital platforms, information systems, communication applications, and monitoring tools used in school management, whereas teaching technologies included digital tools designed mainly for classroom activities. This distinction provided a basis for comparing technology adoption according to its functional relevance to school management.

The management outcomes were assessed across three dimensions: communication, coordination, and monitoring. The correlation analysis was used to examine the strength and direction of the relationships between technology adoption and these management outcomes.

The initial linear regression model used technology adoption as the main explanatory variable and management efficiency as the dependent variable. The results of Model 1 indicated that technology adoption was a significant predictor of management efficiency.

The analysis was then extended by introducing a squared technology-adoption term into the regression model in order to test for a possible nonlinear relationship. This specification was intended to determine whether the association between technology adoption and management efficiency changed as the level of technology use increased.

The analysis also considered differences in digital readiness, staff position, and school size. These controls were included to reduce the possibility that the estimated relationship between technology adoption and management efficiency was driven by differences in institutional or respondent characteristics.

The results were interpreted in relation to the extent to which technologies supported administrative communication, coordination, and monitoring. Particular attention was given to whether technologies directly related to management activities were associated with stronger management outcomes than technologies primarily designed for classroom use.

Table 1. Linear Regression

management_efficie~y	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
technology_adoptio~e	6.973	1.569	4.44	0	3.872	10.074	***
technology_adoptio~2	-.44	.101	-4.36	0	-.64	-.241	***
digital_readiness	2.843	.408	6.98	0	2.038	3.649	***
technology_type	3.499	.613	5.71	0	2.288	4.71	***
active_use	3.549	.894	3.97	0	1.782	5.316	***
school_size	.002	.001	1.90	.06	0	.004	*
staff_role	-.19	.249	-0.77	.445	-.682	.301	
Constant	46.792	5.918	7.91	0	35.092	58.491	***
Mean dependent var	89.247		SD dependent var	5.101			
R-squared	0.582		Number of obs	150			
F-test	28.263		Prob > F	0.000			
Akaike crit. (AIC)	798.632		Bayesian crit. (BIC)	822.717			

*** p<.01, ** p<.05, * p<.1

display -_b[technology_adoption_score]/(2*_b[technology_adoption_score2]) 7.9164258

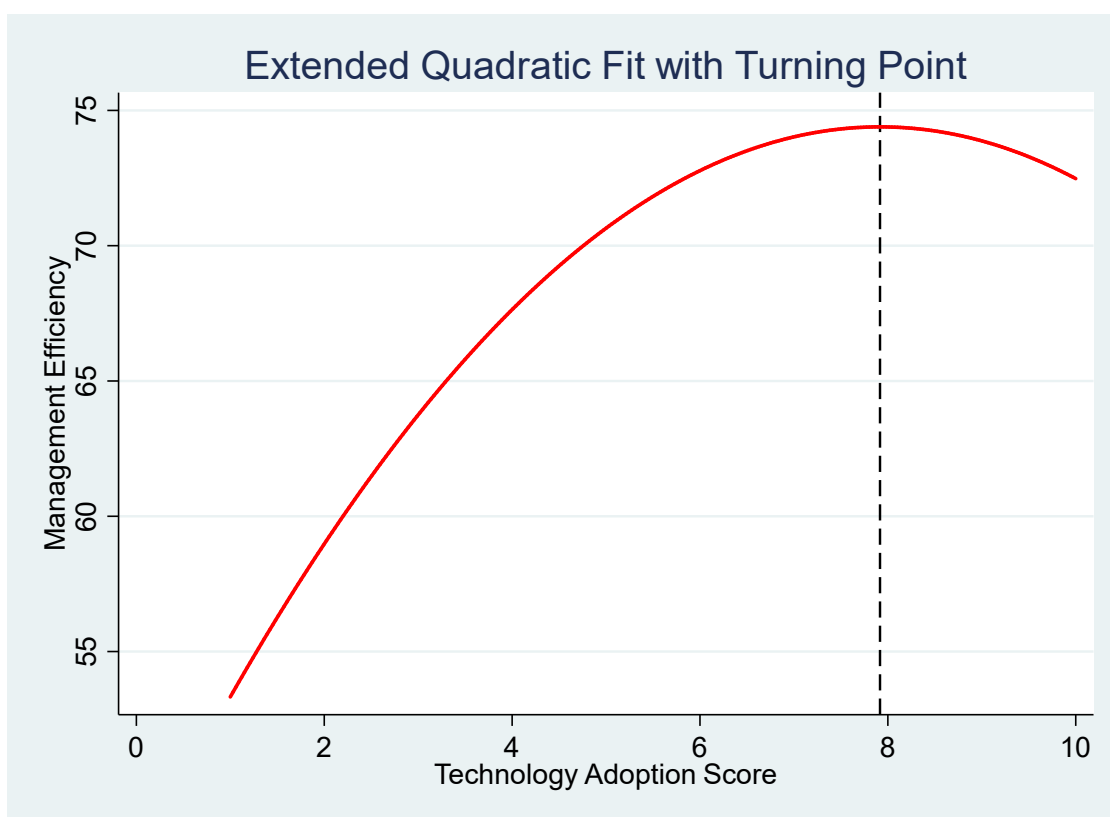
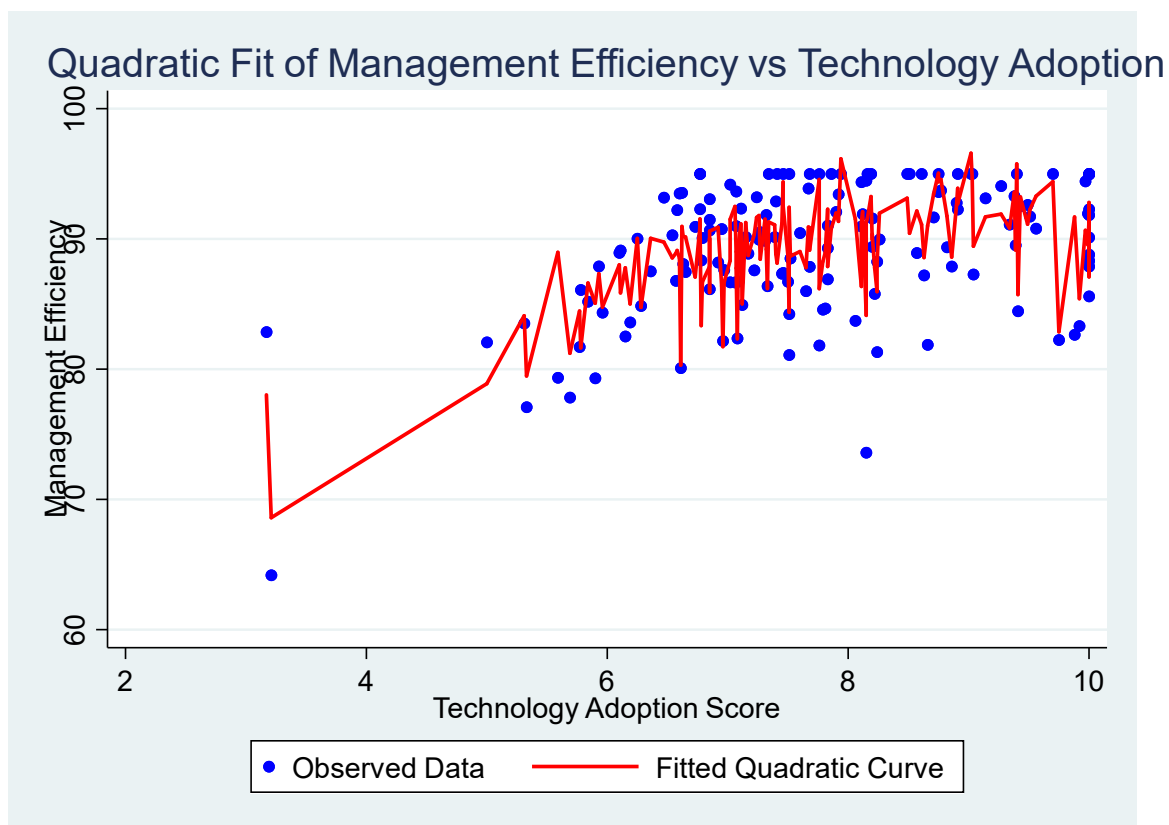


Table 2. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) digital_readin~h	1.000							
(2) admin_relevanc~t	0.830*	1.000						
(3) platform_embed~y	0.860*	0.783*	1.000					
(4) ccm_alignment_~e	0.672*	0.729*	0.806*	1.000				
(5) monitoring_tra~r	0.753*	0.665*	0.811*	0.667*	1.000			
(6) tech_adoption_~y	0.903*	0.882*	0.895*	0.775*	0.788*	1.000		
(7) tech_adoption_~q	0.909*	0.889*	0.890*	0.761*	0.781*	0.998*	1.000	
(8) management_eff~e	0.855*	0.838*	0.878*	0.812*	0.797*	0.955*	0.946*	1.000
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$								

The regression estimates and pairwise correlation results indicate that higher levels of technology adoption are associated with greater management efficiency. In particular, digital tools designed for administrative purposes appear to have a stronger relationship with management outcomes than technologies primarily intended for teaching activities.

The quadratic regression results presented in Table 1 show that technology adoption has a positive linear effect on management efficiency, while the squared technology-adoption term has a statistically significant negative effect. This finding indicates the presence of a nonlinear relationship between technology adoption and management efficiency in private schools.

The estimated turning point of the quadratic specification is 7.916 technology-adoption points. The estimated relationship is positive below this threshold and negative above it. This pattern suggests that increases in technology adoption initially contribute to higher management efficiency, whereas further adoption beyond the estimated turning point may generate diminishing and eventually negative marginal effects.

The pairwise correlation analysis provides additional evidence of a strong relationship between technology adoption and management efficiency. The correlation coefficient between the technology-adoption score and management efficiency is 0.955 and is statistically significant, indicating a very strong positive association between technology use and management outcomes.

The correlation matrix also indicates that staff reported the strongest responses for digital platforms directly related to management activities. This result suggests that technologies used for communication, coordination, and other administrative functions are more closely associated with management efficiency than technologies designed primarily for classroom activities.

The regression results further indicate that digital readiness and technology type are important factors associated with management efficiency. By contrast, the estimated effects of staff role and school size are less consistent across specifications. School size has a weak positive relationship with management efficiency and is statistically significant only at the 10% level. Staff role shows a negative relationship in the quadratic specification, although its estimated effect varies across the models.

Technologies without direct administrative relevance, particularly those designed primarily for teaching activities, appear to have a weaker relationship with management efficiency. Such technologies may contribute less directly to administrative coordination because their primary purpose is to support classroom and instructional activities rather than school management processes.

One possible explanation for the negative coefficient on the squared technology-adoption term is that excessive technology adoption during the digitalization process may eventually reduce management efficiency. Beyond a certain level, additional digital tools may increase complexity, create duplication, or place greater demands on coordination and staff readiness. Within the estimated model, this interpretation is consistent with the identified turning point and the negative coefficient on the squared term.

Overall, the results support the study's hypothesis that technologies directly related to administrative activities are more strongly associated with management efficiency than technologies primarily intended for teaching purposes. At the same time, the nonlinear estimates suggest that the benefits of technology adoption may not increase indefinitely and may depend on the level of digital readiness and the relevance of the technologies to management functions.

The present study demonstrates that technology adoption is an important predictor of management efficiency in private schools. The findings contribute to a better understanding of digitalization from both theoretical and practical perspectives.

More specifically, the quadratic model shows a statistically significant relationship between technology adoption and management efficiency across the selected schools. The positive linear coefficient for technology adoption, together with the negative coefficient on the squared term (-0.440), indicates an inverted U-shaped relationship between technology adoption and management efficiency. The estimated turning point based on the OLS quadratic specification is 7.916 adoption points. Digital readiness also has a positive coefficient, indicating its relevance to the adoption and effective use of management-oriented technologies.

Digital readiness contributes to a greater capacity to adopt new management-oriented and administrative technologies, while the corresponding improvement is less evident for classroom-based technologies. Management outcomes may therefore differ across administrative and teaching technologies depending on the extent to which the tools support the administrative activities of school staff.

The nonlinear estimates presented in Table 1 further indicate that the relationship between technology adoption and management efficiency depends on the level of adoption reported by survey respondents. The results suggest that digital readiness, administrative relevance, reliance on digital platforms, and the avoidance of excessive technology use are important factors associated with management efficiency.

Digital platforms were found to have a positive relationship with management processes. Liu et al. [7] emphasize that such technologies should support coordinated administrative systems by improving communication, monitoring, and decision-making processes.

Accordingly, schools are more likely to improve management processes when activities are coordinated through digital platforms and administrative staff are able to use these systems effectively in decision-making. The findings suggest that digitalization can contribute to the development of a coordination structure within school management. Therefore, administrative tools may need to be integrated into a common digital platform or coordinated more effectively across different departments.

In contrast to the findings reported by Liu et al. [7], the present study indicates that the relationship between technology adoption and management efficiency does not remain continuously positive as the level of adoption increases. Instead, the estimated relationship approaches a saturation point and becomes negative after the estimated turning point.

Most of the estimated relationships remained stable after the inclusion of school size and staff role as control variables. The variables associated with active technology use and technology purpose, particularly the distinction between administrative and teaching tools, were statistically significant and positively associated with management efficiency ($p < 0.01$), with estimated coefficients of 3.549 and 3.499, respectively.

Furthermore, digital readiness and technology adoption were strongly associated with management outcomes, as reflected in their positive coefficients and statistically significant correlations.

These findings suggest that technology adoption contributes more strongly to administrative efficiency when digital tools are directly relevant to management activities. Digital platforms may support staff coordination and real-time monitoring simultaneously, thereby contributing to improvements in school management.

The results differ from those reported by Hakim et al. [4], Mahulae and Panjaitan [8], Prada and Birsyada [11], Sidik et al. [13], and Liu et al. [7]. In particular, the present study identifies a nonlinear relationship between technology adoption and management efficiency in relation to the readiness of the management system (Table 1), whereas such a pattern was not examined in the previous studies considered here.

Liu et al. [7] also identify differences between types of technology and administrative outcomes, including digital communication and activity monitoring, reflecting differences in management purposes and the functions of particular tools. However, similar studies examining the relationship between technology adoption and potential management overload remain limited. Further research could therefore examine different forms of excessive technology adoption in private schools.

Previous studies generally treat technology primarily as a useful management tool rather than as a potential source of excessive administrative burden. The present findings suggest that this distinction may be relevant when evaluating higher levels of technology adoption.

The regression results were generally robust to the inclusion of control variables, although some sensitivity was observed for school size and staff role (Table 1). It is also important to note that the study is limited to selected schools and relies on a standardized survey instrument applied to all respondents.

The technology adoption–management efficiency relationship was estimated using a subsample of 150 complete observations reported in Table 1. Other available records did not contain sufficiently comparable measures of the required variables to be consistently combined with the survey data.

The estimated turning point of 7.916 adoption points may therefore reflect a level close to saturation, after which the estimated marginal relationship changes from positive to negative. In addition, school characteristics such as location and ownership are not fully represented in the model. Consequently, the findings should not be interpreted as establishing a causal effect of technology adoption on management efficiency. The

study identifies correlations and nonlinear associations rather than causal relationships, as experimental and longitudinal methods were not applied.

CONCLUSION AND SUGGESTIONS

This study contributes to the understanding of the relationship between technology adoption and management efficiency in private schools and highlights its practical and administrative implications.

Although the effect of technology adoption is difficult to evaluate in isolation, the findings indicate that, at the observed level of digital adoption, the integration of management platforms and the digital readiness of staff are positively associated with the effectiveness of digitalization as a management instrument for both managers and staff.

Schools should therefore consider the digital readiness of technology users, including teaching staff where relevant, in order to reduce the risk of introducing technologies beyond users' capacity to apply them effectively.

The findings can also help identify which administrative tools are more closely associated with improvements in management efficiency and which technologies are less directly relevant to management outcomes.

The analysis suggests that during digital transformation, when different technologies are being considered, administrative tools are more strongly associated with management-related outcomes than technologies designed primarily for teaching activities.

The survey findings also raise several questions for future research concerning technology adoption, management efficiency, and the decisions required from private schools regarding digitalization. A better understanding of efficiency changes associated with potential technology overload could contribute to the development of more balanced technology-adoption strategies.

Based on the findings, coordination remains one of the key requirements of the digitalization process. In practical terms, technological development in private-school management should therefore remain focused on the core administrative activities for which digital tools are most relevant.

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Proofreader: Xondamir Ismoilov
Layout and Designer: Hasan Maqsudov

2026. № 8

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