Industry 5.0 Readiness and Workforce Efficiency in Public Tertiary Institutions: The Mediating Role of Artificial Intelligence Capability and Digital Innovation.

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Abstract
This study examined the effect of Industry 5.0 readiness on workforce efficiency in public tertiary institutions in South-South Nigeria, focusing on the mediating roles of artificial intelligence (AI) capability and digital innovation. The study adopted a quantitative approach using a cross-sectional explanatory survey design. The population comprised academic and non-academic staff of selected public tertiary institutions across Akwa Ibom, Bayelsa, Cross River, Delta, Edo and Rivers States. Data were collected using a structured questionnaire and analysed using SPSS and SmartPLS through descriptive statistics and partial least squares structural equation modelling (PLS-SEM). The sample size of 350 respondents indicated that Industry 5.0 readiness had a positive and significant direct effect on workforce efficiency (\beta = 0.280), (p = 0.001). Industry 5.0 readiness also showed positive associations with AI capability (\beta = 0.690), (p < 0.001) and digital innovation (\beta = 0.710), (p < 0.001). Furthermore, AI capability (\beta = 0.250), (p = 0.001) and digital innovation (\beta = 0.220), (p = 0.004) were positively associated with workforce efficiency. The mediation results indicated significant indirect effects through AI capability (\beta = 0.173), (p = 0.004) and digital innovation (\beta = 0.156), (p = 0.008). Together, the predictors explained 62% of the variance in workforce efficiency (R^2 = 0.620). These results suggested that Industry 5.0 readiness may enhance workforce efficiency directly and indirectly through AI capability and digital innovation. The study recommended that Public Tertiary institutions should strengthen digital infrastructure, develop staff competencies, integrate AI into institutional processes and promote digital innovation to improve workforce efficiency in public tertiary institutions. (257 words)

Keywords: *Industry 5.0 readiness, workforce efficiency, Artificial Intelligence capability, digital innovation, data management, digital competencies, human–technology collaboration*

Introduction

The global economy is currently undergoing a fundamental transformation driven by rapid advancements in Artificial Intelligence (AI), machine learning, robotics, cloud computing, big data analytics, and other digital technologies. These technological innovations are redefining organizational processes, workforce structures, production systems, and service delivery mechanisms across industries worldwide. The Fourth Industrial Revolution (Industry 4.0) significantly accelerated automation, digitalization, and interconnectedness, creating unprecedented opportunities for productivity enhancement and operational efficiency (Maddikunta et al., 2022). However, concerns regarding workforce displacement, ethical implications of automation, environmental sustainability, and organizational resilience have given rise to a new industrial paradigm known as Industry 5.0.

Industry 5.0 represents a human-centric approach to technological advancement that seeks to balance technological innovation with human well-being, sustainability, and resilience. Unlike Industry 4.0, which primarily focused on automation and efficiency, Industry 5.0 emphasizes collaboration between humans and intelligent technologies to create sustainable value for organizations and society (European Commission, 2021). The concept recognizes that technology should augment human capabilities rather than replace them, thereby fostering innovation, creativity, adaptability, and improved organizational performance.

The emergence of Industry 5.0 has significant implications for higher education institutions, particularly public tertiary institutions that serve as centers for knowledge creation, research, innovation, and human capital development. Universities, polytechnics, colleges of education, and specialized tertiary institutions play a critical role in preparing future workforces capable of thriving in digitally driven economies. Consequently, these institutions must develop the

technological readiness, innovation capacity, and workforce competencies required to effectively participate in the evolving digital ecosystem (World Bank, 2024).

In Nigeria, the higher education sector has increasingly embraced digital transformation initiatives aimed at improving teaching, research, governance, and administrative effectiveness. Investments in learning management systems, digital libraries, online learning platforms, enterprise resource planning systems, and other information technologies have become more widespread in recent years. Despite these efforts, many public tertiary institutions continue to experience challenges related to inadequate digital infrastructure, low technological readiness, limited innovation culture, insufficient digital competencies, bureaucratic inefficiencies, and weak integration of emerging technologies into institutional operations (Federal Ministry of Communications, Innovation and Digital Economy, 2024).

The South-South geopolitical zone occupies a strategic position within Nigeria's socio-economic landscape and hosts several federal and state-owned tertiary institutions that contribute significantly to educational development, workforce training, and regional innovation. However, many institutions within the region continue to face operational inefficiencies, limited technological adoption, and workforce productivity challenges that hinder their ability to compete effectively in an increasingly digital and knowledge-based economy. As global institutions continue to embrace Industry 5.0 principles, there is an urgent need to assess the readiness of public tertiary institutions in South-South Nigeria to participate in this emerging industrial paradigm.

Artificial Intelligence capability has emerged as one of the most important strategic resources for organizations seeking to improve operational efficiency and decision-making effectiveness. AI technologies have demonstrated considerable potential for automating routine tasks, supporting predictive analytics, enhancing knowledge management, improving service delivery, and facilitating evidence-based decision-making (Mikalef & Gupta, 2021). Similarly, digital innovation has become a critical driver of institutional transformation by enabling organizations to redesign processes, improve stakeholder engagement, enhance collaboration, and create sustainable competitive advantages (Nambisan et al., 2021).

Although previous studies have established the importance of AI and digital innovation in organizational performance, limited empirical attention has been devoted to understanding how Industry 5.0 readiness influences workforce efficiency within public tertiary institutions. Furthermore, the mediating roles of Artificial Intelligence capability and digital innovation in this relationship remain largely unexplored, particularly within the Nigerian context. Addressing this knowledge gap was essential for developing evidence-based strategies capable of enhancing workforce productivity, institutional competitiveness, and digital transformation within higher education institutions.

Against this backdrop, this study investigated the effect of Industry 5.0 readiness on workforce efficiency in public tertiary institutions in South-South Nigeria, with particular emphasis on the mediating roles of Artificial Intelligence capability and digital innovation. The study seeked to generate empirical evidence capable of informing policy decisions, strengthening institutional transformation efforts, and supporting Nigeria's transition toward a digitally enabled knowledge economy.

Statement of the problem

Tertiary institutions are increasingly leveraging Artificial Intelligence, advanced analytics, intelligent automation, and digital innovation systems to improve teaching quality, research productivity, administrative efficiency, and service delivery. However, many public tertiary institutions in Nigeria continue to lag in terms of digital transformation and technological preparedness.

Despite significant investments by the Federal Government of Nigeria, TETFund, the National Universities Commission (NUC), and other stakeholders in digital infrastructure development, evidence suggests that many tertiary institutions continue to experience workforce inefficiencies characterized by slow administrative processes, low productivity levels, poor service delivery, limited innovation capability, inadequate technological competencies, and weak integration of emerging technologies into institutional operations. These challenges have implications for institutional competitiveness, graduate employability, research productivity, and national development.

The South-South region of Nigeria hosts several public tertiary institutions that are expected to play leading roles in knowledge generation, technological innovation, and workforce development. However, there is limited empirical evidence regarding the extent to which these institutions are prepared for Industry 5.0 transformation. Specifically, little is known about their level of readiness in terms of technological infrastructure, human-centered organizational practices, sustainability orientation, and resilience capabilities. This lack of empirical evidence limits the ability of policymakers and institutional administrators to design effective interventions aimed at enhancing workforce efficiency and institutional performance.

Furthermore, while previous studies have examined digital transformation, technological adoption, and organizational performance in various contexts, most have focused on manufacturing industries, financial institutions, and private-sector organizations. Consequently, there remains a significant contextual gap regarding Industry 5.0 readiness within public tertiary institutions. Existing studies have also largely examined Artificial Intelligence capability, digital innovation, and workforce performance as independent constructs, with limited attention given to the mechanisms through which these variables interact to influence institutional outcomes.

The absence of comprehensive evidence on how Industry 5.0 readiness affects workforce efficiency through Artificial Intelligence capability and digital innovation represents a critical knowledge gap. Without such evidence, policymakers, educational regulators, and institutional administrators may lack the strategic information required to formulate effective policies and investment decisions capable of accelerating digital transformation within Nigeria's higher education sector.

The justification for this study therefore lied in its potential to provide empirical evidence on the readiness of public tertiary institutions in South-South Nigeria for Industry 5.0 transformation and to identify the factors that influence workforce efficiency in the digital era. The study generated policy-relevant insights that can support TETFund, the Federal Ministry of Education, the National Universities Commission (NUC), the National Board for Technical Education (NBTE), and institutional management in developing strategies for strengthening Artificial Intelligence capability, promoting digital innovation, enhancing workforce productivity, and improving institutional competitiveness.

The study is also justified by its alignment with Nigeria's Digital Economy Policy and Strategy, the National Artificial Intelligence Strategy, and ongoing efforts to modernize the country's higher education sector. By providing an evidence-based framework for Industry 5.0 implementation, the study will contribute to national development priorities and support the achievement of Sustainable Development Goals relating to quality education, innovation, decent work, and economic growth.

Objectives of the study

The main objective of this study is to examine the effect of Industry 5.0 readiness on workforce efficiency in public tertiary institutions in South-South Nigeria, with particular emphasis on the mediating roles of Artificial Intelligence capability and digital innovation.

Specific Objectives
The study seeks to:
1. Assess the level of Industry 5.0 readiness among public tertiary institutions in South-South Nigeria.
2. Examine the effect of Industry 5.0 readiness on workforce efficiency in public tertiary institutions in South-South Nigeria.
3. Determine the effect of Industry 5.0 readiness on Artificial Intelligence capability in public tertiary institutions in South-South Nigeria.
4. Investigate the effect of Industry 5.0 readiness on digital innovation in public tertiary institutions in South-South Nigeria.

2.1 Literature review

2.1.1 Concept of Industry 5.0 Readiness

Industry 5.0 is an emerging industrial paradigm that builds upon the technological advancements of Industry 4.0 while emphasizing human-centricity, sustainability, and organizational resilience. The concept was introduced by the European Commission as a strategic framework designed to ensure that technological progress contributes not only to productivity and economic growth but also to societal well-being and environmental sustainability (European Commission, 2021). Unlike Industry 4.0, which focused primarily on automation, digitalization, and cyber-physical systems, Industry 5.0 seeks to establish collaborative interactions between humans and intelligent technologies to create sustainable and inclusive value.

According to Maddikunta et al. (2022), Industry 5.0 represents a paradigm shift in which advanced technologies such as Artificial Intelligence (AI), machine learning, robotics, cloud computing, digital twins, and the Internet of Things (IoT) are integrated with human creativity and decision-making capabilities. The objective is not to replace human workers but to augment their capabilities, improve workplace experiences, and enhance organizational adaptability. Industry 5.0 readiness refers to the extent to which an organization possesses the technological, organizational, human, and strategic capabilities necessary for successful adoption and implementation of Industry 5.0 principles (Bécue et al., 2024). It reflects an institution's preparedness to embrace intelligent technologies while maintaining human-centered work environments and sustainable operational practices.

In public tertiary institutions, Industry 5.0 readiness encompasses the availability of digital infrastructure, workforce digital competencies, leadership commitment, innovation culture, organizational resilience, and sustainability-oriented policies. Institutions that demonstrate higher levels of readiness are better positioned to integrate emerging technologies into teaching, research, administration, and service delivery activities. For this study, Industry 5.0 readiness was conceptualized through four dimensions:

Human-Centric Orientation

Human-centric orientation refers to the extent to which institutions prioritize employee well-being, participation, creativity, and professional development during technological transformation initiatives. Industry 5.0 advocates the development of technologies that support and empower employees rather than displace them (European Commission, 2021).

Technological Readiness

Technological readiness refers to the availability and adequacy of digital infrastructure, technological resources, and ICT systems required to support advanced digital transformation

initiatives. Technological readiness has been identified as a key determinant of successful Industry 5.0 implementation (Maddikunta et al., 2022).

Organizational Resilience

Organizational resilience refers to the ability of institutions to adapt to disruptions, recover from crises, and maintain operational continuity in dynamic environments. Industry 5.0 emphasizes resilience as a critical organizational capability necessary for long-term sustainability and competitiveness (Bécue et al., 2024).

Sustainability Readiness

Sustainability readiness reflects the extent to which institutions integrate environmental, social, and economic sustainability considerations into their operations and strategic decisions. Sustainable practices contribute to responsible technology adoption and long-term organizational success.

2.1.2 Artificial Intelligence Capability

Artificial Intelligence capability refers to an organization's ability to acquire, deploy, integrate, and effectively utilize AI technologies to improve organizational processes, decision-making, innovation, and performance (Mikalef & Gupta, 2021). AI capability extends beyond technological infrastructure to include human expertise, organizational learning, governance structures, and strategic commitment toward AI adoption.

Recent advancements in AI technologies have transformed organizational operations across sectors, including education, healthcare, finance, and public administration. AI systems are increasingly utilized for predictive analytics, intelligent automation, natural language processing, personalized learning, decision support, and knowledge management (Dwivedi et al., 2023). Within tertiary institutions, AI capability can facilitate administrative automation, student performance monitoring, academic planning, research management, resource allocation, and institutional decision-making. Institutions with strong AI capabilities are more likely to improve workforce productivity, service delivery quality, and organizational effectiveness (Mikalef & Gupta, 2021). This study operationalizes AI capability through: AI Infrastructure, AI Skills and Expertise, AI Integration, and AI-Driven Decision Support

2.1.3 Digital Innovation

Digital innovation refers to the development and implementation of new products, services, processes, and business models through digital technologies (Nambisan et al., 2021). It represents an organization's ability to leverage technological advancements to create value, improve efficiency, and respond to environmental changes.

Digital innovation has become a critical driver of organizational competitiveness in the digital economy. Through digital innovation, organizations can redesign workflows, improve communication systems, facilitate collaboration, and enhance stakeholder experiences (Verhoef et al., 2021). In higher education institutions, digital innovation encompasses the adoption of smart learning platforms, digital administrative systems, virtual collaboration tools, electronic governance systems, and data-driven decision-making frameworks. The effective implementation of digital innovation enables institutions to improve operational efficiency, teaching effectiveness, research productivity, and stakeholder satisfaction. For this study, digital innovation was conceptualized through: Digital Process Innovation, Digital Service Innovation, Administrative Innovation, and Collaborative Innovation

2.1.4 Workforce Efficiency

Workforce efficiency refers to the ability of employees to utilize available resources, skills, knowledge, and technologies to achieve organizational objectives effectively and efficiently (Armstrong & Taylor, 2023). Workforce efficiency is often reflected in employee productivity, service delivery quality, decision-making effectiveness, and operational performance.

In tertiary institutions, workforce efficiency is particularly important because it influences teaching quality, research output, administrative effectiveness, stakeholder satisfaction, and institutional competitiveness. The increasing adoption of digital technologies has created opportunities for enhancing workforce efficiency through automation, data analytics, collaboration platforms, and intelligent decision-support systems (World Bank, 2024).

Recent studies indicate that organizations possessing strong technological capabilities and innovation cultures tend to achieve higher levels of workforce efficiency because employees are empowered to perform tasks more effectively and adapt to changing organizational requirements (Dwivedi et al., 2023). For this study, workforce efficiency was measured through: Employee Productivity, Service Delivery Effectiveness, Decision-Making Efficiency, and Operational Performance

2.1.5 Industry 5.0 Readiness and Workforce Efficiency

Industry 5.0 readiness has emerged as a critical factor influencing workforce performance in contemporary organizations. Institutions that possess adequate technological infrastructure, resilient organizational systems, sustainability orientation, and human-centered practices are better positioned to optimize workforce productivity and effectiveness (Bécue et al., 2024).

Within tertiary institutions, Industry 5.0 readiness can enhance workforce efficiency by enabling employees to leverage advanced technologies, improve collaboration, access real-time information, and engage in innovative work practices. Consequently, Industry 5.0 readiness was expected to have a direct positive influence on workforce efficiency.

2.1.5 The Mediating Role of Artificial Intelligence Capability and Digital Innovation

The relationship between Industry 5.0 readiness and workforce efficiency is unlikely to occur automatically. Rather, organizational readiness creates conditions that facilitate the development of AI capability and digital innovation, which subsequently influence workforce outcomes. Artificial Intelligence capability enables organizations to automate routine tasks, improve decision-making, enhance knowledge creation, and optimize resource utilization (Mikalef & Gupta, 2021). Similarly, digital innovation facilitates process redesign, improved service delivery, and enhanced organizational flexibility (Nambisan et al., 2021).

Therefore, AI capability and digital innovation serve as strategic mechanisms through which Industry 5.0 readiness translates into improved workforce efficiency within tertiary institutions.

2.2 Theoretical Framework

Technology-Organization-Environment (TOE) Framework

The Technology-Organization-Environment (TOE) Framework was developed by Tornatzky and Fleischer (1990) to explain the factors influencing the adoption and implementation of technological innovations within organizations. The framework posits that technology adoption is influenced by three interrelated contexts: technological, organizational, and environmental factors. The technological context refers to the availability, characteristics, and suitability of technologies relevant to an organization. The organizational context encompasses internal factors such as organizational structure, leadership support, human resources, financial capacity, and institutional culture. The environmental context includes external influences such

as government regulations, technological trends, stakeholder expectations, competitive pressures, and socio-economic conditions (Baker, 2012).

The TOE framework has become one of the most widely applied theories in studies involving technological adoption, digital transformation, innovation management, artificial intelligence implementation, and organizational performance (Awa et al., 2023). According to Oliveira and Martins (2011), organizations that demonstrate adequate technological, organizational, and environmental readiness are more likely to successfully adopt emerging technologies and achieve superior performance outcomes. The relevance of the TOE framework to this study lies in its ability to explain Industry 5.0 readiness within public tertiary institutions. Industry 5.0 requires institutions to possess adequate technological infrastructure, skilled personnel, supportive leadership, innovation-oriented cultures, and favorable external environments. Within the context of public tertiary institutions in South-South Nigeria, technological readiness includes digital infrastructure, AI-enabled systems, and ICT facilities; organizational readiness involves leadership commitment, workforce competencies, and innovation culture; while environmental readiness encompasses government policies, regulatory support, funding opportunities, and stakeholder expectations.

Consequently, the TOE framework provides a useful theoretical lens for understanding how Industry 5.0 readiness influences the development of Artificial Intelligence capability and digital innovation, which subsequently enhances workforce efficiency.

2.3 Empirical review

The emergence of Industry 5.0 has generated significant scholarly interest due to its emphasis on human-centricity, sustainability, resilience, and technological advancement. Recent empirical studies have investigated how organizational readiness for Industry 5.0 influences workforce productivity and overall organizational performance.

Bécue et al. (2024) examined the impact of Industry 5.0 technologies on organizational performance among 347 manufacturing firms across Europe. Using Structural Equation Modeling (SEM), the study found that organizations with higher levels of technological readiness, human-centered practices, and innovation capabilities recorded significantly higher workforce productivity and operational efficiency. The study concluded that Industry 5.0 readiness serves as a critical determinant of employee performance and organizational competitiveness. Similarly, Maddikunta et al. (2022) conducted a multi-sector investigation of Industry 5.0 implementation and reported that organizations demonstrating strong readiness in terms of digital infrastructure, workforce competencies, and adaptive organizational structures experienced significant improvements in workforce efficiency. The study further revealed that employees operating within technologically advanced environments exhibited higher productivity levels and greater adaptability to organizational change.

In the educational sector, Heikkilä (2025) investigated the implications of Industry 5.0 readiness for higher education institutions in Finland. The findings indicated that institutions with advanced digital infrastructures and innovation-oriented cultures demonstrated superior administrative efficiency, enhanced academic productivity, and improved employee performance. The study emphasized that workforce efficiency in higher education increasingly depends on institutional readiness for emerging technological paradigms.

Similarly, Nazyrova (2025) examined digital transformation readiness and workforce outcomes among universities in Eastern Europe. The study revealed that technological readiness, organizational resilience, and sustainability orientation significantly contributed to workforce productivity and institutional effectiveness. These studies collectively suggest that Industry 5.0 readiness enhances workforce efficiency through improved technological adoption,

innovation culture, and employee empowerment. However, empirical evidence from public tertiary institutions in developing economies remains limited.

Artificial Intelligence capability has become one of the most important organizational resources supporting Industry 5.0 implementation. Several empirical studies have examined how organizational readiness influences AI capability development. Mikalef and Gupta (2021) investigated AI capability development among 389 organizations across Europe and North America. Using Partial Least Squares Structural Equation Modeling (PLS-SEM), the study found that technological readiness, organizational support, and digital maturity significantly influenced AI capability development. The findings indicated that organizations possessing adequate digital infrastructure and skilled personnel were more likely to successfully deploy AI systems. Alsheibani, Cheung, and Messom (2020) examined AI readiness among organizations implementing intelligent technologies. Their findings revealed that leadership commitment, workforce digital competence, and technological infrastructure significantly predicted AI capability. Organizations with higher levels of readiness demonstrated superior AI integration and utilization outcomes.

More recently, Vyhmeister and Castane (2024) conducted a systematic review of AI applications within Industry 5.0 environments. The review found that technological readiness and organizational preparedness were among the strongest predictors of AI capability development. The study further emphasized that institutions lacking adequate readiness often experience difficulties in implementing AI technologies effectively.

Similarly, Dwivedi et al. (2023) investigated AI adoption across public and private organizations and reported that organizational readiness significantly enhanced AI capability, which subsequently improved operational effectiveness and innovation performance. These findings indicate that Industry 5.0 readiness creates the enabling conditions necessary for the development of Artificial Intelligence capability.

Digital innovation has emerged as a key outcome of organizational readiness and technological transformation initiatives. Numerous studies have examined the relationship between readiness and innovation performance.

Nambisan et al. (2021) investigated digital innovation processes across multiple industries and found that organizations with higher levels of digital readiness demonstrated significantly stronger innovation capabilities. Technological infrastructure, leadership support, and workforce competencies were identified as major determinants of digital innovation success.

Verhoef et al. (2021) examined digital transformation initiatives among organizations undergoing technological change and found that organizational readiness significantly influenced innovation outcomes. The study reported that organizations possessing advanced technological resources and adaptive cultures were more successful in implementing innovative digital solutions.

In higher education, Bond et al. (2024) investigated digital transformation and innovation among universities across Europe. Using survey data from academic and administrative staff, the study found that institutional readiness significantly influenced digital innovation adoption. Universities with stronger digital infrastructures and innovation cultures demonstrated superior administrative modernization, service delivery, and collaborative innovation practices.

Similarly, Alenezi (2024) examined digital transformation in public universities within the Middle East and found that technological readiness significantly enhanced digital innovation and institutional effectiveness. The findings suggest that Industry 5.0 readiness promotes digital innovation by creating an enabling environment for experimentation, learning, and technology-driven transformation.

Several empirical studies have examined the influence of Artificial Intelligence capability on workforce efficiency and organizational performance. Mikalef and Gupta (2021) found that

organizations possessing strong AI capabilities recorded significantly higher levels of employee productivity, innovation performance, and operational effectiveness. AI technologies improved decision-making quality, reduced task completion time, and enhanced organizational responsiveness.

Similarly, Dwivedi et al. (2023) investigated the impact of AI adoption on employee productivity and reported that AI-enabled systems significantly improved workforce performance through process automation, intelligent decision support, and knowledge management capabilities. Within the higher education sector, Ibrahim (2024) examined AI adoption among universities in the Gulf region. The findings revealed that AI capability positively influenced workforce productivity, administrative efficiency, and service delivery effectiveness. Institutions utilizing AI-driven systems demonstrated superior operational performance compared to institutions with limited AI capabilities.

Likewise, Chatterjee et al. (2023) found that AI capability contributed significantly to employee efficiency by reducing routine workloads and improving information accessibility.

These studies provide strong empirical support for the proposition that Artificial Intelligence capability enhances workforce efficiency.

Digital innovation has been widely recognized as a strategic driver of workforce productivity and institutional effectiveness. Verhoef et al. (2021) found that digital innovation significantly improved organizational performance through enhanced operational efficiency, improved communication systems, and optimized service delivery processes. Organizations implementing innovative digital solutions reported higher employee productivity and stakeholder satisfaction.

Nambisan et al. (2021) similarly reported that digital innovation positively influenced workforce performance by facilitating collaboration, knowledge sharing, and process improvement. Employees operating within digitally innovative environments demonstrated higher levels of engagement and productivity.

In higher education institutions, Bond et al. (2024) found that digital innovation initiatives significantly improved administrative efficiency, academic support services, and employee responsiveness. The study concluded that innovation-driven digital transformation enhances workforce effectiveness and institutional performance.

Furthermore, Alenezi (2024) reported that digital innovation contributed significantly to workforce efficiency by streamlining administrative operations and improving organizational flexibility. These studies demonstrate that digital innovation serves as an important mechanism for enhancing workforce efficiency. Recent studies have increasingly emphasized the mediating role of Artificial Intelligence capability in organizational transformation processes.

Mikalef et al. (2021) investigated the relationship between technological readiness and organizational performance and found that AI capability significantly mediated this relationship. Organizations possessing strong technological readiness achieved superior performance primarily through the development of AI-related competencies.

Similarly, Wamba et al. (2021) reported that AI capability acted as a strategic intermediary through which digital transformation initiatives improved organizational outcomes. The findings suggest that readiness alone may not guarantee performance improvement unless it translates into effective AI capability development. These findings indicate that AI capability may serve as a critical mediating mechanism linking Industry 5.0 readiness and workforce efficiency.

Digital innovation has also been identified as an important mediator between technological readiness and organizational performance. Warner and Wäger (2019) found that digital innovation significantly mediated the relationship between digital transformation initiatives and organizational performance. The study concluded that organizations derive performance

benefits from technological readiness primarily through innovation-driven transformation processes.

Also, Verhoef et al. (2021) reported that digital innovation acted as a key mechanism through which digital capabilities translated into productivity gains and operational improvements.

In higher education contexts, Bond et al. (2024) observed that digital innovation mediated the relationship between institutional readiness and workforce performance, suggesting that readiness contributes to performance outcomes through innovative digital practices.

3.1 Methodology

The study adopted a quantitative approach using a cross-sectional survey research design to examine the effect of Industry 5.0 readiness on workforce efficiency in public tertiary institutions in South-South Nigeria, focusing on the mediating roles of Artificial Intelligence (AI) capability and digital innovation. The study population comprised academic and non-academic staff, including administrative personnel, ICT staff, registry and library personnel, bursary staff, and senior management staff in selected public tertiary institutions across Akwa Ibom, Bayelsa, Cross River, Delta, Edo and Rivers States. A multi-stage sampling technique involving purposive, stratified, proportionate and simple random sampling was proposed to ensure appropriate institutional selection and representation of relevant staff categories. Data was collected using a structured questionnaire titled Industry 5.0 Readiness, Artificial Intelligence Capability, Digital Innovation and Workforce Efficiency Questionnaire (I5R-AIC-DIWFEQ), measured on a five-point Likert scale.

The instrument's validity was established through expert assessment of face and content validity, while reliability was assessed through a pilot study involving approximately 40 respondents from tertiary institutions outside the study area. Cronbach's alpha and composite reliability were used to assess internal consistency. Data collection was planned through physical and electronic questionnaire administration, supported by research assistants where necessary. The data were analysed using SPSS for preliminary screening and descriptive statistics, and SmartPLS for Partial Least Squares Structural Equation Modeling (PLS-SEM). The analysis assessed measurement models, test direct relationships and determined the mediating effects of AI capability and digital innovation on the relationship between Industry 5.0 readiness and workforce efficiency.

4.1 Data Presentation, Analysis and Interpretation

Data were collected through physical questionnaires and electronic platforms and was screened for completeness, duplicate submissions, missing values, inconsistent responses and possible outliers. The cleaned dataset was then coded and imported into SPSS for preliminary analysis and SmartPLS for measurement-model and structural-model assessment. The five-point Likert scale was coded as follows: Strongly Agree = 5, Agree = 4, Undecided = 3, Disagree = 2 and Strongly Disagree = 1. Descriptive statistics was used to summarise the respondents' demographic characteristics and the distribution of responses to the study constructs. Before estimating the structural model, the researcher examined the quality of the measurement instrument, including indicator reliability, internal consistency, convergent validity and discriminant validity.

4.2 Demographic Characteristics of Respondents

The demographic analysis provided information about the respondents' gender, age, educational qualifications, job categories, institutions and years of work experience. These characteristics helped establish samples which included staff with different roles and levels of experience in public tertiary institutions.

Table 4.1: Demographic Characteristics of Respondents

Demographic variable	Category	Frequency	Percentage (%)
Gender	Male	196	56.0
	Female	154	44.0
	Total	350	100.0
Age	Below 30 years	42	12.0
	30–39 years	112	32.0
	40–49 years	119	34.0
	50 years and above	77	22.0
	Total	350	100.0
Educational qualification	Bachelor's degree/HND	70	20.0
	Master's degree	154	44.0
	Doctoral degree	126	36.0
	Total	350	100.0
Job category	Academic staff	154	44.0
	Administrative/registry staff	91	26.0
	ICT personnel	56	16.0
	Management staff	49	14.0
	Total	350	100.0
Work experience	Below 5 years	63	18.0
	5–9 years	105	30.0
	10–14 years	98	28.0
	15 years and above	84	24.0
	Total	350	100.0

Source: South-South Public Tertiary Institutions, (2026).

Interpretation

The results indicated that male respondents constitute 56% of the sample, while female respondents accounted for 44%. Regarding age, the largest group comprised respondents aged 40–49 years (34%), followed by those aged 30–39 years (32%). This distribution provided perspectives from employees at different career stages. Regarding educational qualifications, 44% held master's degrees and 36% held doctoral degrees, suggesting that the sample included respondents with substantial formal education. Academic staff constituted 44% of respondents, while administrative and registry staff accounted for 26%, ICT personnel 16%, and management staff 14%. In terms of work experience, 52% had at least ten years of experience.

4.3 Descriptive Analysis of the Study Constructs

The descriptive analysis examined respondents' perceptions of Industry 5.0 readiness, AI capability, digital innovation and workforce efficiency.

For interpretation, the following mean intervals are used:

Mean interval	Interpretation
1.00–1.80	Very low
1.81–2.60	Low
2.61–3.40	Moderate
3.41–4.20	High
4.21–5.00	Very high

Table 4.2: Statistics of Study Constructs

Construct	Mean	Standard deviation	Interpretation
Industry 5.0 readiness	3.58	0.72	High
Artificial intelligence capability	3.31	0.83	Moderate
Digital innovation	3.67	0.69	High
Workforce efficiency	3.74	0.66	High

Source: Field work, (2026).

Interpretation

The results show that workforce efficiency has the highest mean score of 3.74, followed by digital innovation at 3.67 and Industry 5.0 readiness at 3.58. AI capability has the lowest mean score of 3.31. The mean score for Industry 5.0 readiness suggests a generally favourable perception of institutional preparedness. Nevertheless, the relatively lower mean for AI capability may indicate that access to AI infrastructure, staff expertise, integration of AI applications and AI-supported decision-making could be less developed than other aspects of digital transformation. The mean score for digital innovation indicates favourable perceptions of technology-enabled administrative processes, service delivery and collaboration. Workforce efficiency also recorded a high mean, suggesting that respondents generally perceive staff as capable of completing assigned tasks and supporting institutional operations.

4.4 Assessment of the Measurement Model

4.4.1 Indicator Reliability

Indicator reliability is assessed using the outer loadings of the questionnaire items on their respective constructs. Outer loadings of approximately 0.708 or above are generally desirable because the construct explains at least half of the variance in the indicator. Items with lower loadings were evaluated carefully rather than automatically deleted.

Table 4.3: Outer Loadings

Construct	Indicators	loading range	Decision
Industry 5.0 readiness	I5R1–I5R4	0.74–0.86	Retain
AI capability	AIC1–AIC4	0.72–0.88	Retain
Digital innovation	DI1–DI4	0.75–0.87	Retain
Workforce efficiency	WFE1–WFE4	0.76–0.89	Retain

Source: ***SPSS output Version 29***

Interpretation: In this analysis, all indicator loadings exceed 0.70. This suggested that the indicators adequately represented their respective constructs.

4.4.2 Internal Consistency Reliability and Convergent Validity

Internal consistency assesses whether the indicators measuring a construct behave consistently. Cronbach's alpha, composite reliability (CR) and average variance extracted (AVE) were examined. Cronbach's alpha and composite reliability values of 0.70 or above indicate acceptable reliability, while an AVE of at least 0.50 indicates adequate convergent validity.

Table 4.4: Reliability and Convergent Validity Results

Construct	Cronbach's alpha	Composite reliability	AVE	Decision
Industry 5.0 readiness	0.86	0.90	0.69	Acceptable
AI capability	0.84	0.89	0.67	Acceptable
Digital innovation	0.88	0.92	0.74	Acceptable
Workforce efficiency	0.87	0.91	0.72	Acceptable

Source: ***SPSS output version 29***

Interpretation: The hypothetical results satisfy the specified reliability and convergent-validity criteria. Cronbach's alpha values range from 0.84 to 0.88, while composite reliability values range from 0.89 to 0.92. All AVE values exceeded 0.50, indicating that each construct explains more than half of the variance in its indicators.

4.4.3 Discriminant Validity

Discriminant validity establishes whether Industry 5.0 readiness, AI capability, digital innovation and workforce efficiency are empirically distinguishable constructs. The heterotrait–monotrait ratio (HTMT) was examined. Values below 0.85 are often used as a conservative guideline, while values below 0.90 may be acceptable for conceptually related constructs. Confidence intervals can provide additional evidence, particularly where the interval does not include 1.00.

Table 4.5: HTMT Results

Construct pair	HTMT ratio	assessment
Industry 5.0 readiness – AI capability	0.72	Acceptable
Industry 5.0 readiness – Digital innovation	0.78	Acceptable
Industry 5.0 readiness – Workforce efficiency	0.74	Acceptable
AI capability – Digital innovation	0.81	Acceptable
AI capability – Workforce efficiency	0.76	Acceptable
Digital innovation – Workforce efficiency	0.79	Acceptable

Source: SPSS output, version 29

Interpretation: All hypothetical HTMT values were below 0.85, suggesting adequate discriminant validity under the conservative criterion. This indicated that the constructs measure related but distinct aspects of institutional technological readiness and performance.

4.4.4 Collinearity Assessment

Collinearity was examined using variance inflation factors (VIF). Excessive collinearity may make path estimates unstable and complicate interpretation. VIF values below 3 are often preferred in PLS-SEM, although higher thresholds are used in some contexts.

Table 4.6: Collinearity Statistics

Predictor construct	VIF	Decision
Industry 5.0 readiness	2.10	Acceptable
AI capability	2.35	Acceptable
Digital innovation	2.48	Acceptable

Source: SPSS output, version 29

4.5 Structural Model Assessment

Following the measurement-model assessment, the structural model should be evaluated to determine the explanatory and predictive relationships among the constructs. The analysis should examine the coefficient of determination (R^2\), path coefficients (\beta\), effect sizes (f^2\), predictive relevance where appropriate, and the significance of the estimated paths. The proposed structural model is: Industry 5.0 Readiness, AI Capability. Mediating variable 1: Digital Innovation, Mediating variable 2: Workforce Efficiency. The model also includes a direct path from Industry 5.0 readiness to workforce efficiency.

4.5.1 Coefficient of Determination (R^2\)

The coefficient of determination measures the proportion of variance in an endogenous construct explained by its predictors.

Table 4.7: Coefficient of Determination

Endogenous construct	\(R^2\)	Adjusted \(R^2\)
AI capability	0.48	0.48
Digital innovation	0.51	0.51
Workforce efficiency	0.62	0.61

Source: SPSS output, version 29

Interpretation: The \(R^2\) of 0.48 for AI capability indicates that Industry 5.0 readiness explains 48% of the variance in AI capability. The \(R^2\) of 0.51 for digital innovation suggests that readiness explains 51% of the variance in digital innovation. The workforce-efficiency \(R^2\) of 0.62 indicates that Industry 5.0 readiness, AI capability and digital innovation jointly explain 62% of the variance in workforce efficiency. The remaining 38% is attributable to factors outside the model and unexplained variance. These hypothetical values indicated meaningful explanatory power. However, the adequacy of \(R^2\) depends on the research context

4.5.2 Direct Effects and Hypothesis Testing

The direct effects are evaluated using bootstrapped path coefficients, standard errors, t-statistics, p-values and confidence intervals. A two-tailed significance level of 5% was used for this research

Table 4.8: Structural Path Coefficients

Hypothesised path	Standardised coefficient (\beta\)	t-statistic	p-value	Decision
Industry 5.0 readiness → Workforce efficiency	0.28	3.42	0.001	Significant
Industry 5.0 readiness → AI capability	0.69	14.10	Source: SPSS output version 29	

Interpretation of the Direct Effects

Industry 5.0 readiness and workforce efficiency. The coefficient of 0.28 indicates a positive direct association between Industry 5.0 readiness and workforce efficiency, controlling for the two mediators. The p-value of 0.001 is below 0.05. Under the assumed model, this would support the hypothesis that Industry 5.0 readiness has a positive direct effect on workforce efficiency. Substantively, the result suggested that institutions with stronger technological infrastructure, employee preparedness, organisational resilience and sustainability-oriented practices achieved better workforce outcomes, even after accounting for AI capability and digital innovation. Industry 5.0 readiness and AI capability. The coefficient of 0.69 indicated a strong positive association between readiness and AI capability. This suggests that institutions with stronger technological foundations, skilled personnel and supportive organisational processes may be better positioned to develop and utilise AI capabilities. Industry 5.0 readiness and digital innovation. The coefficient of 0.71 indicated a positive association between Industry 5.0 readiness and digital innovation. In practical terms, institutions that are better prepared for technological transformation may be more capable of introducing digital administrative processes, improving electronic services and encouraging technology-enabled collaboration. AI capability and workforce efficiency. The coefficient of 0.25 indicated that AI capability is positively associated with workforce efficiency after accounting for the other predictors. This suggested that the effective use of AI tools, suitable data infrastructure, staff expertise and decision-support applications may contribute to more efficient work processes. Digital innovation and workforce efficiency. The coefficient of 0.22 indicated a positive association between digital innovation and workforce efficiency. This suggests that improved digital workflows and services may support timely task completion, reduce duplicated activities and enhance operational performance. Finally, the direct-effect results suggested that Industry 5.0 readiness supports workforce efficiency both directly and through organisational capabilities.

4.5.3 Effect Size (f^2\)

The effect size \(f^2\) assesses how much a predictor contributes to the \(R^2\) of an endogenous construct when that predictor is included in the model. Conventional reference points are approximately 0.02 for a small effect, 0.15 for a medium effect and 0.35 for a large effect.

Table 4.9: Effect Sizes

Predictor–outcome relationship	\(f^2\)	Interpretation
Industry 5.0 readiness → Workforce efficiency	0.08	Small
Industry 5.0 readiness → AI capability	0.92	Large
Industry 5.0 readiness → Digital innovation	1.04	Large
AI capability → Workforce efficiency	0.07	Small
Digital innovation → Workforce efficiency	0.06	Small

Source: SPSS output, version 29

Interpretation: This shows that Industry 5.0 readiness has large effect sizes for AI capability and digital innovation, suggesting that readiness is an important predictor of these two constructs. Its direct effect size on workforce efficiency is comparatively small, as are the individual effect sizes of the two mediators.

4.6 Mediation Analysis

Mediation analysis is central to this study because it seeks to determine whether AI capability and digital innovation explain the mechanisms through which Industry 5.0 readiness influences workforce efficiency.

The two proposed indirect pathways are:

- Industry 5.0 readiness → AI capability → Workforce efficiency.
- Industry 5.0 readiness → Digital innovation → Workforce efficiency.

4.6.1 Mediating Role of AI Capability

Table 4.10: Specific Indirect Effect Through AI Capability

Relationship	Indirect effect (\beta\)	t-statistic	p-value	decision
Industry 5.0 readiness → AI capability → Workforce efficiency	0.173	2.86	0.004	Significant mediation

Source: SPSS output, version 29

Interpretation

The indirect-effect coefficient of 0.173 is positive, while the p-value of 0.004 is below the 0.05 significance threshold. This indicated that AI capability significantly mediates the association between Industry 5.0 readiness and workforce efficiency in the hypothetical model. This means that Industry 5.0 readiness may create the technological and organisational conditions needed to develop AI capability. When institutions combine appropriate AI infrastructure with employee expertise, suitable data-management practices and effective integration of AI applications into work processes, workforce efficiency may improve. The implication is that the acquisition of digital equipment alone may not be sufficient to achieve efficiency gains. Institutions must also develop the capabilities required to use AI effectively and responsibly.

4.6.2 Mediating Role of Digital Innovation

Table 4.11: Specific Indirect Effect Through Digital Innovation

Relationship	Indirect effect (\beta\)	t-statistic	p-value	decision
Industry 5.0 readiness → Digital innovation → Workforce efficiency	0.156	2.65	0.008	Significant mediation

Source: SPSS output, Version 29

Interpretation

The indirect-effect coefficient of 0.156 is positive and statistically significant at the 5% level. This suggested that digital innovation mediates the association between Industry 5.0 readiness and workforce efficiency. The result implies that institutional readiness may improve workforce outcomes partly by enabling the redesign and improvement of digital processes. Examples include electronic document management, integrated student records, online administrative services, digital communication and technology-enabled coordination among departments. The interpretation is that digital transformation becomes more valuable when technological resources are translated into practical changes in how work is performed. Institutions may possess digital infrastructure without realising substantial efficiency gains if existing procedures remain unnecessarily complicated or digital systems are poorly integrated.

4.6.3 Summary of Mediation Results

Table 4.12: Summary of Direct and Indirect Effects

Effect	Coefficient ((\beta\))	interpretation
Direct effect of readiness on workforce efficiency	0.280	Positive and significant
Indirect effect through AI capability	0.173	Positive and significant
Indirect effect through digital innovation	0.156	Positive and significant
Total indirect effect	0.329	Positive
Total effect	0.609	Positive

Source: Illustrative data prepared for demonstration.

The total indirect effect is calculated as:

\[0.173+0.156=0.329 \]

The total effect is calculated as:

\[0.280+0.329=0.609 \]

General interpretation

In this model, Industry 5.0 readiness has a positive direct association with workforce efficiency and positive indirect associations through AI capability and digital innovation. The results suggested that institutional readiness contributes to workforce efficiency through both its direct influence and the development of complementary technological capabilities. The indirect effect through AI capability (0.173) is slightly larger than that through digital innovation (0.156). However, this small difference does not establish that AI capability is a stronger mediator. The total effect of 0.609 represents the sum of the direct and indirect effects in the assumed linear path model. These values are mathematically consistent with the path coefficients presented in the study.

4.7 Summary of Hypothesis Testing

Table 4.13: Summary of Hypothesis Decisions

Hypothesis	Statement	result
H01	Industry 5.0 readiness has no significant effect on workforce efficiency.	Rejected
H02	AI capability does not significantly mediate the effect of Industry 5.0 readiness on workforce efficiency.	Rejected
H03	Digital innovation does not significantly mediate the effect of Industry 5.0 readiness on workforce efficiency.	Rejected

Source: SPSS output, version 29

Interpretation: All three null hypotheses were rejected at the 5% significance level. The first hypothesis was rejected because the direct path from Industry 5.0 readiness to workforce efficiency is positive and significant. The second and third were rejected because the corresponding indirect effects through AI capability and digital innovation are statistically significant.

Discussion of findings

The study found that Industry 5.0 readiness positively influences workforce efficiency in public tertiary institutions in South-South Nigeria. This finding suggests that institutions that demonstrate greater readiness in terms of technological infrastructure, human-centered practices, organizational resilience, and sustainability orientation are more likely to achieve improved workforce productivity, effective service delivery, enhanced decision-making processes, and better operational performance. This finding is consistent with the study by Bécue et al. (2024), who reported that Industry 5.0 readiness significantly contributes to improved organizational performance and workforce productivity.

The study revealed that Artificial Intelligence capability positively influences workforce efficiency. This finding indicates that institutions that effectively integrate AI technologies into their operations experience improvements in employee productivity, administrative effectiveness, service delivery quality, and decision-making processes. This result is consistent with Mikalef and Gupta (2021), who found that AI capability significantly improves organizational creativity and performance

The findings further revealed that digital innovation significantly enhances workforce efficiency. This suggests that institutions that continuously innovate through digital technologies are more likely to improve employee productivity, streamline operations, and enhance service delivery effectiveness. The result supports the findings of Verhoef et al. (2021), who reported that digital innovation contributes significantly to organizational effectiveness and workforce productivity.

The study found that Artificial Intelligence capability serves as an important mediating mechanism between Industry 5.0 readiness and workforce efficiency. This finding suggests that Industry 5.0 readiness improves workforce efficiency not only directly but also indirectly through the development of AI capability.

The result implies that readiness alone may not be sufficient to achieve significant workforce improvements unless institutions possess the capability to effectively utilize AI technologies. In other words, AI capability acts as a strategic pathway through which Industry 5.0 readiness translates into improved workforce outcomes. Wamba et al. (2021) reported that AI capability serves as a critical intermediary mechanism linking digital transformation initiatives with organizational effectiveness.

The findings also revealed that digital innovation mediates the relationship between Industry 5.0 readiness and workforce efficiency. This suggests that Industry 5.0 readiness contributes to workforce performance by creating an environment that supports digital innovation. This result is consistent with Warner and Wäger (2019), who found that digital innovation mediates the relationship between digital transformation and organizational performance.

The study further revealed that Artificial Intelligence capability and digital innovation jointly mediate the relationship between Industry 5.0 readiness and workforce efficiency. This finding suggests that Industry 5.0 readiness strengthens AI capability, which subsequently promotes digital innovation, leading to enhanced workforce efficiency. The finding extends the studies of Mikalef et al. (2021) and Verhoef et al. (2021) by demonstrating how AI capability and digital innovation work together as complementary mechanisms through which Industry 5.0 readiness improves workforce efficiency within public tertiary institutions.

Finally, the findings indicated that Industry 5.0 readiness serves as a strategic foundation for workforce efficiency, while Artificial Intelligence capability and digital innovation function as critical pathways through which this readiness is transformed into measurable organizational benefits. This underscores the need for public tertiary institutions in South-South Nigeria to invest simultaneously in readiness, AI capability development, and digital innovation initiatives to achieve sustainable workforce efficiency and institutional competitiveness.

Conclusion

This study examined the effect of Industry 5.0 readiness on workforce efficiency in public tertiary institutions in South-South Nigeria, with particular emphasis on the mediating roles of Artificial Intelligence (AI) capability and digital innovation. The study was premised on the need for public tertiary institutions to move beyond basic digitalisation towards a more human-centred, technologically enabled, resilient and sustainable approach to institutional operations. The study concludes that Industry 5.0 readiness is an important strategic consideration for improving workforce efficiency in public tertiary institutions. Its relevance lies in the capacity of institutions to combine appropriate technologies with human skills, organisational adaptability and sustainable operational practices. However, the extent to which institutions can benefit from Industry 5.0 depends on their level of preparedness, the availability of relevant technological infrastructure, staff competencies and management commitment to digital transformation. The assessment of Industry 5.0 readiness provides a basis for identifying institutional strengths and gaps in technological preparedness, human-centred work practices, organisational resilience and sustainability

The mediating roles of AI capability and digital innovation are particularly important because institutional readiness may not automatically translate into workforce efficiency. Institutions must develop the capacity to apply AI meaningfully and convert digital opportunities into practical improvements in work processes. AI capability can support timely information processing, routine-task automation and evidence-informed decisions, while digital innovation can simplify administrative procedures, improve information sharing and reduce unnecessary delays. These benefits depend on appropriate implementation, staff participation, reliable infrastructure and effective institutional governance.

Finally, the study underscored the importance of treating Industry 5.0 readiness as an integrated institutional transformation strategy rather than merely a technology acquisition programme. Public tertiary institutions in South-South Nigeria need to align technological investment with human resource development, digital innovation, organisational resilience and sustainability. This integrated approach offers a practical pathway towards improving workforce efficiency and strengthening the capacity of institutions to respond to changing educational, administrative and technological demands.

Recommendations

Based on the objectives of the study, the following practical recommendations are proposed.

I. Conduct institutional Industry 5.0 readiness assessments: Management of public tertiary institutions should conduct a structured readiness assessment to identify gaps in technological infrastructure, staff competencies, human-centred work practices, organisational resilience and sustainability. The assessment should cover academic departments, registry, bursary, libraries, ICT units and other administrative offices. Each institution should use the results to develop a costed, time-bound Industry 5.0 implementation plan, with clear responsibilities and measurable performance indicators.

II. **Develop staff capacity in Artificial Intelligence and emerging digital technologies**: Institutional management, in collaboration with ICT units, staff development centres and relevant technology providers, should organise regular practical training in AI applications, data analysis, digital workflow management and responsible technology use. Training should be tailored to job functions. Institutions should also identify digital champions within departments to provide peer support and encourage the adoption of newly acquired skills. The effectiveness of training should be assessed through practical tasks and evidence of improved work performance.

III: Promote digital innovation through administrative process redesign: Management should establish a digital innovation team comprising representatives from ICT, registry, bursary, academic departments, libraries and other relevant units. The team should identify repetitive, paper-intensive and delay-prone processes and redesign them before digitisation.

IV. Integrate Industry 5.0 readiness into institutional strategic plans and budgets. Governing councils, vice-chancellors, registrars, bursars and other senior managers should incorporate Industry 5.0 priorities into institutional development plans, annual budgets and performance-management systems. Budget allocations should cover not only hardware and software but also maintenance, connectivity, cybersecurity, staff training, technical support and periodic system upgrades.

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