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Artificial intelligence technologies usage for improved service delivery in Uganda

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Background: Rapid advancements in artificial intelligence (AI) technologies have provided opportunities to improve public service delivery. Uganda is committed to leveraging opportunities presented by AI technologies to improve service delivery.

Aim: This study examines how the Ugandan government uses AI technologies to enhance public service delivery.

Setting: Few studies have been conducted exploring how AI technologies are used to improve public service delivery in Uganda. To bridge this knowledge gap, this study examines the ways in which AI technologies have been used in public service delivery by the government of Uganda.

Methods: Using a mixed-methods approach, secondary and primary data were collected. Textual content analysis and Microsoft Excel 2016 were used to analyse qualitative and quantitative data respectively to obtain results and insights for the study.

Results: The results reveal that the Ugandan government is deploying AI technologies in various agencies to enhance efficiency and productivity, improve accuracy and precision, solve environmental challenges, enhance fraud detection and security, and enable personalisation and customisation of citizen-centric services. Furthermore, this study discusses the ethical concerns and social implications of adopting AI technologies such as data privacy, security threats, the digital divide and job displacement.

Conclusion: Recognising the transformative potential of AI technologies to overcome traditional public service barriers, ethical concerns and social implications should be considered in the implementation to yield sustainable outcomes in Uganda.

Contribution: This study contributes to the body of knowledge on AI adoption in Africa, and provides insights for policymakers and researchers seeking to understand and/or recommend AI technologies utilisation to optimise public service delivery.

Keywords: artificial intelligence; AI technologies; technology; public service delivery; Uganda; Africa; efficiency; performance; governance; AI ethics.

Introduction

Technological advancements in this era of the Fourth Industrial Revolution (4IR), with artificial intelligence (AI) at the forefront, have revolutionised the way governments deliver services to citizens. Artificial intelligence is a set of technologies that enable computers 'to perform tasks that would typically require human intelligence, for example, visual perception, speech recognition, decision-making, language translation, and problem solving' (Meroueh & Chen 2023:32). Established in the 1950s as an academic discipline, with research focussing on enabling a machine to exhibit human-like intelligent behaviour, AI has undergone ground-breaking practical advancements (Haenlein & Kaplan 2019:5). Advancements in machine learning have revolutionised AI applications into practical tools whose capabilities can be integrated into various industries and are slowly becoming an integral part of our daily lives (Fanti, Guarascio & Moggi 2022:410).

Having not fully participated in the development and use of technologies in the First, Second and Third Industrial Revolutions, African governments, including Uganda, are committed to not being left behind. Transformative AI technologies offer the potential to optimise resource allocation and enhance decision-making processes in the public sector. The opportunities presented by AI technologies have enabled governments across the globe to utilise them in diverse sectors to enhance the delivery of public services and improve citizens' quality of life.

Notwithstanding the existing challenges that Uganda faces associated with inadequate infrastructure, limited resources and inefficient bureaucratic processes, AI technologies present unique opportunities to redefine and transform the way public services are administered and delivered.

The primary objective of this study is to examine the use of AI technologies to improve public service delivery in Uganda. To achieve this objective, this study begins by reviewing the literature on the evolution of AI to understand its current applications (Haenlein & Kaplan 2019:6). The study then explores the ways in which AI technologies have been adopted globally for public service delivery. Using a mixed-methods methodology, this study analyses the utilisation of AI technologies by the Ugandan government and deliberates on the potential challenges arising from AI integration in the delivery of public services in Uganda.

Historical progression in artificial intelligence technologies

Since its inception in the 1950s as a theoretical concept, AI has undergone a dramatic transformation to evolve into a practical technology applied in diverse domains. The term 'artificial intelligence' was first coined at the Dartmouth Conference in 1956, when research focussed on symbolic reasoning and expert systems (Haenlein & Kaplan 2019:7; Meroueh & Chen 2023:32). These early research efforts laid the foundation for modern advancements in Natural Language Processing (Khurana et al. 2023:3721) whose power of language understanding and analysis is currently transforming the delivery of public services by governments. The advancements in rule-based systems in the 1960s and the 1970s, which involved writing explicit rules to mimic human intelligence or the capabilities of human experts, resulted in logic programming (Li, Diouf & Gorkhali 2022:419). Logic programming, which uses rules and logical reasoning to make decisions and solve problems, has recently been used in public institutions to automate routine and rule-based decision-making tasks such as the application of permits or licences.

In the 1980s, the idea of neural networks, inspired by the structure and functions of the human brain, was introduced (Fanti et al. 2022:415). The emergence of machine learning in the 1990s marked a pivotal shift in the AI trajectory. Artificial intelligence research revolutionised the capabilities of neural networks, support vector machines and decision trees allowing for speech recognition and image classification (Fanti et al. 2022:416; Haenlein & Kaplan 2019:8). With the rise of big data and computational power in the 2000s, natural language processing advanced into statistical and deep learning models, propelling AI applications in sentiment analysis, machine translation and question-answering systems (Khurana et al. 2023:3722). In the 2010s, AI evolved from edge detection algorithms to convolutional neural networks, providing remarkable accuracy in tasks such as object recognition, image generation and facial recognition (Fanti et al. 2022:417). Recent research on the integration of AI with robotics has opened new possibilities for industrial automation (Sethi & Sarangi 2017:17), autonomous vehicles (Uwizeyimana 2022:2), humanoid robots (Nalubega & Uwizeyimana 2019:4), space exploration (Ingrand & Ghallab 2017:17) and drones (Nalubega & Uwizeyimana 2019:7).

The current AI subfields that focus on different aspects of intelligent systems include machine learning, natural learning processing, computer vision, robotics, expert systems, reinforcement learning, knowledge representation and reasoning, planning and scheduling, and data mining.

Machine learning, which includes supervised learning, unsupervised learning, reinforcement learning and deep learning (Richter et al. 2022:2) focusses on the development of algorithms and models that enable systems to automatically learn and improve from data without being explicitly programmed (Meroueh & Chen 2023:32). Deep learning algorithms have achieved remarkable breakthroughs in the fields of image and speech recognition, and autonomous driving (Fanti et al. 2022:413).

The subfield of natural language processing, comprising text mining, sentiment analysis, machine translation, question answering and language generation, generally focusses on enabling computers to understand, interpret and generate human language (Khurana et al. 2023:3723). Natural language processing techniques are used in applications such as virtual assistants, language translation and sentiment analysis (Khurana et al. 2023:3730). The computer vision subfield involves the processing, analysis and understanding of visual information from images and videos (Yang 2022:3). The tasks performed include object recognition, image classification, image segmentation, facial recognition and scene understanding (Yang 2022:3).

The subfield of robotics merges AI with mechanical engineering, electronics and computer science to design and develop intelligent machines capable of performing physical tasks autonomously or with minimal human assistance (Ingrand & Ghallab 2017:10). This subfield involves areas such as robot perception, motion planning, robot control and human-robot interaction (Ingrand & Ghallab 2017:33). The expert systems subfield involves mimicking human expertise in specific domains, such as medicine, finance, and engineering, to solve complex problems and provide expert-level advice or make decisions (Haenlein & Kaplan 2019:8).

The reinforcement learning subfield focusses on training agents to interact with the environment and learn optimal behaviour through trial and error (Richter et al. 2022:3; Taddy 2018:4). Reinforcement learning algorithms use rewards and punishments to guide the learning process of the agent (Taddy 2018:4). The subfield of knowledge representation and reasoning focusses on representing and organising knowledge to enable reasoning and inference (Fanti et al. 2022:418). The planning and scheduling subfield comprises planning that

involves generating sequences of actions to achieve a desired goal and scheduling that deals with allocating resources over time to optimise performance (Fanti et al. 2022:418).

The AI field is continually evolving, with new subfields emerging as the research progresses. The evolution of AI from its early conceptualisation to the present has been marked by periods of breakthroughs amid challenges. The potential of AI remains boundless in terms of contributing transformative benefits to industries and humanity as a whole. Artificial intelligence technologies are poised to improve service delivery by revolutionising how governments interact with citizens, streamline operations and make data-driven decisions. This article provides insight into global cases in which governments have used AI technologies to enhance public service delivery.

Global cases on the use of artificial intelligence technologies in delivering public service

The speed at which governments across the globe are exploring AI technologies to improve service delivery not only expresses the breadth of AI applications but also provides insight into the possible depth of its ability to exponentially disrupt the nature of public service delivery. Artificial intelligence technologies have the potential to impact virtually all industries in various sectors, blur geographical boundaries and enable new business models and services with intelligent automation capabilities. Despite the existing infrastructural limitations and regulatory considerations, governments such as the United Kingdom (UK), the United States (US), Estonia and Rwanda are using AI technologies to deliver public service.

A report from the UK Committee on Standards in Public Life (2020:15) showed that the UK government is using AI technologies in the healthcare sector, judiciary, police departments, transportation departments and the home office. According to the report, the local government of the Hampshire County Council is using 'smart devices like Amazon Echo in the homes of adults receiving social care in order to bridge the gap between visits from professional cares' (UK Committee on Standards in Public Life 2020:15). The South Wales Police Department uses AI-powered video surveillance systems for real-time monitoring of large events such as sports events and public protests and responds accordingly (Fontes et al. 2022:5). The Blackpool Council uses AI technology to detect road damage using satellite images (BBC News 2020).

The government of the US is actively implementing AI technologies in its military structures for intelligence gathering, threat detection and battlefield planning. Artificial intelligence technologies are used in US healthcare to collect and analyse patient data from multiple sources to enable physicians to monitor patient health (Ahuja 2019:8). Federal police departments use AI-powered video surveillance systems for facial recognition, video analytics and predictive policing in law enforcement to identify suspects and analyse crime patterns (Fontes et al. 2022:5). The US Internal Revenue Service uses AI-powered bots to assist taxpayers behind on tax payments by setting up for them a payment plan (Fagan 2023:4). The US National Oceanic and Atmospheric Administration deploys AI technologies to analyse large amounts of data collected from satellites and sensors to provide accurate weather forecasts and monitor environmental conditions (Bateman 2020).

Through e-government initiatives, the Estonian government has integrated AI technologies to enable seamless interoperability. Its e-residency and AI-powered data identity systems can perform identity verification, fraud prevention and related cybersecurity programs (Misuraca & Noordt 2020:16). Estonian police use AI algorithms to analyse crime data, identify patterns and predict potential criminal activities (Fagan 2023:4). The city of Viimsi uses AI technologies to monitor and analyse real-time wind, tides, wave information and timely weather reports to the public (Westergren, Jonsson & Velsberg 2019). The International Telecommunication Union reported that the Estonian government is using AI technologies to identify sentiments from emergency calls on traffic accidents and to make quicker decisions (International Telecommunication Union 2020). The Information System Authority of Estonia deployed Bürokratt, an AI-powered virtual voice assistant that provides personalised assistance and support to citizens (Information System Authority 2022).

The government of Rwanda partnered with Babyl Health Rwanda to extend telemedicine, in particular, the AI-powered Symptom Checker, to analyse the patient's symptoms and provide clear, accurate information on the potential causes and possible next steps (Fagan 2023:3). The Rwandan government has integrated the use of AI-powered chatbots and virtual assistants to provide information and services to citizens (Schenker 2021).

These global cases on the use of AI technologies for public service delivery demonstrate the multi-sector applications of these technologies spanning healthcare, law enforcement, environmental monitoring, roads, and events management, and beyond (Nyathi 2023). It is argued that AI is currently used to conduct diplomatic relations among countries (Niyitunga 2022:20). However, there are hardly any studies that have been conducted to examine how the Ugandan government is exploring AI technologies for delivering public services. To bridge this knowledge gap, this study attempts to examine Ugandan government public services in which AI technologies have been integrated.

Research methods and design

The study employed a mixed methods approach, in which qualitative and quantitative techniques were used concurrently in an explanatory research design to collect detailed data to obtain comprehensive results for the study. With this research design, quantitative data were first collected and

analysed, followed by qualitative data collection and analysis to derive meaningful valid results and make credible conclusions. Among the quantitative methods, this study used the secondary review method to obtain data from credible public government datasets and reports. The qualitative methods of the study considered written text extracted from credible official government websites, reports, targeted interviews and media posts. This study adhered to all ethical considerations related to data collection and analysis. During the collection of data using interviews, informed voluntary consent from the key respondents was verbally sought before the interview, and the anonymity of the respondents as well as the confidentiality of the data were ensured. Ethical clearance was granted by the School of Public Management, Governance and Public Policy at the University of Johannesburg Research Ethics Committee (code: 21PMGPP4).

Quantitative secondary data were collected from both the published report and the anonymised raw dataset for the Uganda National 2022 Information Technology (IT) survey. The Uganda National 2022 IT survey was conducted by the Uganda National Information Technology Authority (NITA). National Information Technology Authority is a government agency responsible for ensuring that IT solutions, products and services in Uganda meet government standards, are implemented according to guidelines and regulations, and therefore conduct regular surveys to inform the government on the status of the information technologies and create a repository for existing technologies. The methodology of the Uganda National 2022 IT Survey report highlighted that the government of Uganda has 132 Government Ministries, Departments and Agencies (MDAs), of which 116 were sampled and 95 responded, yielding a response rate of approximately 82% (NITA 2022:14).

The quantitative data from the National 2022 IT Survey report provided foundational descriptive statistics on the current status of the Ugandan government on IT usage for public service delivery. The data included MDAs' access to the Internet; percentage of MDAs with functional computers and laptops; MDAs with institutional official websites, emails and mobile applications and those using them to deliver public services; MDAs using cloud computing services and where their databases are hosted; MDAs with official social media profiles with details on their most used social media platform; the percentage of cyber-security incidents recorded and percentage of MDAs that had integrated AI technologies in the delivery of public services. The anonymised dataset for the Uganda National 2022 IT Survey provided further statistics and details on which MDAs integrated AI technologies in the delivery of public services. This secondary dataset was considered in this study because of its availability and ability to reliably provide credible data and information at a lower cost in terms of time and finances regarding AI technology usage for public service delivery in Uganda. Upon identifying the MDAs from the dataset, qualitative methods were used for further data collection and analysis.

Qualitative data were collected from written text extracted from credible official government websites, reports and social media posts as well as targeted in-depth interviews with key respondents in the six identified MDAs. Convenience sampling was used to select the key respondent for the in-depth interview from the MDA to obtain detailed insight into how this particular MDA used AI technologies to deliver public services. Convenience sampling was used because each of these six MDAs had a long staff list, whose contacts were not accessible to the researchers. The researchers reached out to at least two key people per MDA through direct social media messaging, and only those willing to voluntarily participate in the study were considered. Ten key respondents from six MDAs participated in the in-depth interviews, with a target sample of 12 respondents yielding a response rate of approximately 83%. The respondents' anonymity and confidentiality of the collected data were ensured. To ensure data credibility, integrity and validity of the information collected from websites and social media posts, the information was double-checked by cross-referencing it with other reliable sources such as government archival reports.

Quantitative data from the anonymised dataset were analysed using Microsoft Excel 2016 to obtain descriptive statistics. The quantitative data were imported from the database of the anonymised raw dataset for the Uganda 2022 IT survey into Microsoft Excel 2016. The frequencies represented in terms of per cent were calculated using descriptive statistics. The quantitative data from the Uganda 2022 IT survey report were captured per record.

The qualitative data collected in the in-depth interviews with key respondents, websites, reports and social media, were transcribed and organised for textual content analysis. A coding scheme was developed with categories representing AI technology usage and/or integration in public services in Uganda.

With the study objective in focus, the collected data were coded in line with a coding scheme to obtain an in-depth understanding of the data. The analysis involved interpreting the content of the coded data, identifying underlying meanings, integrating data in a systematic manner to ensure compatibility and consistency, noting the data limitations, drawing conclusions and making interpretations based on the patterns identified in connection to the study objective.

All ethical considerations related to data storage and analysis of the datasets and the anonymity and confidentiality of the respondents were ensured.

Ethical considerations

Ethical clearance to conduct this study was obtained from the University of Johannesburg, CBE Research Ethics Committee (Reference no. 21PMGPP4).

Results

Use of information and communications technology in delivering public services

The findings from the quantitative data analysis revealed that all MDAs had access to the Internet, with 97.9% of them having functional computers and laptops to perform office tasks (NITA 2022:26). It was reported that 97.9% of the MDAs owned institutional websites (NITA 2022:34) and 94.7% of the MDAs provided institutional emails to their staff (NITA 2022:32). However, only 86.3% of MDAs use their official websites to deliver public services, 87.4% use emails and 28.4% use mobile applications to serve the public (NITA 2022:34). Online services were delivered predominantly through web applications (71.4%) and only 39.3% through mobile applications (NITA 2022:36). The findings further disclosed that 64.2% of the MDAs embraced cloud computing services, with 54.1% hosting their applications and databases in the government data centre (NITA 2022:41).

The quantitative data analysis showed that 81.1% of the MDAs use social media to deliver public services, with MDAs having official profiles on Twitter (91.6%), Facebook (82.1%), WhatsApp (40%), YouTube (37%), LinkedIn (21%) and Instagram (16%) (NITA 2022:35). Cyber security incidences in MDAs were noted in the quantitative data analysis, revealing that 59% of MDAs had experienced them during the previous 12 months (NITA 2022:15).

These findings further revealed that 21% of the MDAs were taking steps towards integrating 4IR technologies into the delivery of public services (NITA 2022:15). Analysing the anonymised dataset revealed that, of the 21% of the MDAs that had indicated that they made steps towards integrating 4IR technologies, 29% had integrated AI technologies in the delivery of public services.

Integration of artificial intelligence technologies in public service delivery

The findings from the qualitative data analysis confirmed that six MDAs had integrated AI technologies into the delivery of public services. These included the Uganda Investment Authority (UIA), Uganda Revenue Authority (URA), Uganda National Meteorological Authority (UNMA), Uganda Electricity Transmission Company Limited (UETCL), Uganda Electricity Distribution Company Limited (UEDCL), and Kampala Capital City Authority (KCCA).

Artificial intelligence technologies for improved customer queue management

Qualitative analysis revealed that AI technology is used to manage customer queues at points of delivering public services, specifically at the UIA. The UIA uses a customer relationship management (CRM) digital solution in which AI technologies are integrated. A CRM system is designed to collect, utilise, manage and improve customer data with the support of technological solutions to develop a long-term exceptional customer experience and relationship (Ledro et al. 2022:49). The UIA is a semi-autonomous government investment promotion agency responsible for marketing investment opportunities, promoting packaged investment projects, and offering business support, advisory and advocacy services in Uganda.

The UIA has a digital one-stop centre with a CRM system. Different departments and affiliated agencies use similar systems at different customer contact points. A study key respondent from UIA explained:

> 'UIA has a task to drive Uganda's economic growth and development and therefore it ensures that local and foreign investors have access to relevant information about the business environment, markets investment opportunities, and provides related advisory and advocacy services'. (Respondent 1, Male)

The key respondent further elaborated that the head offices of UIA have a physical one-stop centre that houses 14 government agencies and private sector institutions whose services are needed to facilitate the investment process. With all these agencies, the respondent emphasised that managing the customers' time in the queue is critical, considering that the process of obtaining all the required documents is not a 1-day activity.

The key respondent explained:

> 'UIA is using an AI-powered queue management system which is embedded in our CRM solution to manage customers' waiting experience throughout the entire customer journey. The AI-powered queue management system embedded in the CRM solution used at UIA schedules customers' appointments through estimations of the expected number of customers on a particular date and time using information in the database.' (Respondent 2, Female)

The key respondent further explained that the CRM database stores the details of UIA customers such as information about their history and interactions at the UIA, their current status and their outstanding issues that need to be addressed. The key respondent expressed satisfaction with the improvements witnessed, stating:

> 'The AI-powered system of innovation has significantly decreased the actual waiting pre-service and post-service time of our customers. It also provides us with real-time data which assists in adequate staff planning and allows for increased mobility of our staff.' (Respondent 2, Female)

With the incorporation of AI technologies in the queue management system embedded in its CRM system, the UIA therefore efficiently manages the queue at its one-stop centres, by managing customers' waiting experience throughout the entire customer journey. The results conclusively indicate that the use of an AI-powered system promotes the efficiency and effectiveness of the services delivered by the UIA. The AI-powered system accurately schedules customer appointments by estimating the expected number of customers on a particular date and time using information from the database. This significantly decreases the actual pre- and post-service waiting times of their customers. The AI-powered system

additionally provides real-time data for management, which assists inadequate staff planning and allows for increased mobility of the staff.

Artificial intelligence technologies for effective revenue collection

The qualitative data analysis revealed that AI technologies have been used to improve revenue collection in Uganda. The findings indicate that the URA has integrated AI technologies into its operations to efficiently and effectively collect revenue, protect society from undesirable and harmful products and advise on trade policy matters. Respondent 3 from URA informed the study that URA uses a computerised customs management system called Automated Systems for Customs Data (ASYCUDA) to strategically improve taxpayers' compliance and enhance public revenue collection:

> 'The AI system which is integrated in the ASYCUDA software, automates some of the repetitive procedures like online research of market prices, and filtering of research results'. (Respondent 3, Female)

> 'URA uses this system to better profile and manage risks, detect fraud and compliance, and conduct customs audits, a strategy that has assisted in improving revenue collection and trade facilitation'. (Respondent 3, Female)

The key respondent additionally informed the study that:

> 'URA had customs transit challenges in the previous arrangements, such as long periods taken to clear cargo, the loss of goods in transit, and the many days that were undertaken to physically escort the cargo to its destination center. The adoption of a web-based electronic cargo tracking system has assisted URA in minimizing the use of physical escorts while efficiently monitoring and controlling the cargo activities at different command centers in real-time'. (Respondent 3, Female)

Artificial intelligence technologies have, therefore, enabled URA to upgrade its role of trade facilitation from the gatekeeping role. Through AI and data analytics, the URA has positioned itself better in profiling and managing risks, detecting fraud and compliance, and conducting customs audits, thereby improving revenue collection and trade facilitation.

Artificial intelligence technologies for timely and accurate weather predictions and modelling

Findings from the qualitative analysis indicate that AI technologies used for weather prediction and modelling are consistent with global cases noted in the literature where both the US and Estonian governments deployed AI technologies to provide accurate weather forecasts. In Uganda, the findings reported that the UNMA uses AI technology to provide accurate weather predictions and modelling. Previously, the forecasters at UNMA worked with atmospheric computer models to manually input observation findings obtained from the atmosphere, land or water, and then assimilate the data with information drawn from weather stations located at key points across the country to forecast the weather. Weather prediction involves providing weather reports to the public regarding ongoing measurements of temperature, wind speed, pressure, precipitation and amount of cloud cover. Predicting the type of weather in the next few hours, 24 h or weeks is the aim of weather prediction and modelling.

Respondent 5 from UNMA informed the study that since the launch of the AI-based forecasting computer for weather prediction and modelling in early 2022, more accurate and timely information about weather has been recorded:

> 'The more accurate weather information has assisted the public in getting early warnings which could save lives and property'. (Respondent 5, Male)

> 'Using an AI-based forecasting supercomputer eliminates the manual input of data'. (Respondent 5, Male)

Respondent 6 explained that data from weather stations located at key points across the country is collected, received and processed in real time. Respondent 6 further explained that the AI-based forecasting computer accesses these data in real time from Internet of things (IoT) devices installed to collect weather parameters from weather stations located at key points across the country:

> 'The data captured by IoT devices are instantly stored and transmitted to the supercomputer'. (Respondent 6, Female)

The key respondent deduced that the use of AI-based forecasting supercomputer systems has promoted efficiency and effectiveness by providing timely, reliable and accurate weather information. More accurate weather information could potentially provide the public with early warnings that could save lives and property.

Artificial intelligence technologies for safe and reliable electricity transmission

The qualitative analysis further indicated that Uganda uses AI technology to ensure the safe and reliable transmission of electricity. This initiative is under the UETCL, a government agency responsible for the development, operation and maintenance of high-voltage power transmission lines (above 33 kV). Respondent 7 informed the study that UETCL incorporated a smart software application called Supervisory Control and Data Acquisition (SCADA) to safely and reliably transmit electricity across Uganda. The respondent further explained that the SCADA system is a standalone smart platform that gathers real-time data from communication generated by IoT devices placed in remote locations. The respondent continued to explain that the SCADA system sounded alarms when hazardous faults and conditions were detected, which allowed for quick rectification, and hence efficient control and monitoring of all equipment on the electricity grid.

The use of AI-powered SCADA by UETCL therefore enables the timely and quick rectification of hazardous faults and conditions detected.

Artificial intelligence technologies for efficient electricity distribution

Qualitative findings revealed that Uganda uses AI technologies to efficiently distribute electricity by UEDCL, a government

agency responsible for distributing electricity below 33 kV. Respondent 9 informed the study that since 2005, UEDCL leased a private operator, Umeme for 20 years to invest, operate and maintain these electricity distribution networks in Uganda. In the concession arrangement of the Lease and Assignment Agreement, the primary role of UEDCL is to monitor and oversee the investment requirements for the assets and to ensure that Umeme implements the best investment and operational practices.

Respondent 9 further informed the study that Umeme adopted the use of the automated meter reading in 2014, but has, since 2019, upgraded to the advanced smart prepayment metering solution to manage electricity payment losses and improve efficiencies. The smart prepayment metering solution, as explained by the respondent, allows real-time two-way communication between the customer and the utility provider's server. The respondent further explained that this smart solution provides real-time monitoring of the power consumed by the customer and provides notification in case of any detected meter tampering and meter bypass.

Respondent 10 in UEDCL acknowledged that the smart prepayment metering solution has reduced the company's operational costs incurred on the physical monitoring of meters by hiring a team of contractors, and significantly assisted in the reduction of electricity theft.

Artificial intelligence technologies solved the challenges of electricity theft and high operational costs for the company. This was achieved by enabling real-time monitoring of customer power consumption and providing notifications in case of any detected meter tampering or bypass.

Artificial intelligence technologies for efficient management of air quality

Additionally, the qualitative data findings revealed that AI technology is used to manage air quality in the capital city of Uganda. This initiative was undertaken by the KCCA, the governing body of the Capital City of Uganda, Kampala and administers it on behalf of the Central Government. Respondent 11 from KCCA informed the study that Kampala Capital City was ranked among the most polluted cities in the 2021 World Air Quality Report. According to the respondents, the major sources of pollution were dust from unpaved roads, open burning of solid waste, exhaust and non-exhaust emissions from vehicles, industrial emissions and domestic biomass energy use. Respondent 12 stated that KCCA uses AI technologies to monitor and curb air pollution in Kampala. The respondent further explained that KCCA undertook deliberate interventions to curb air pollution by installing more than 100 air quality sensors across the city. These sensors monitor real-time air quality data, which are then analysed, interpreted and understood to make better decisions for the authorities. Real-time air quality data are accessible to the public through smartphone applications. The respondent informed the study that AI technologies have assisted the KCCA in efficiently and effectively managing the air pollution challenges in Kampala.

Discussion

Recent academic publications have highlighted the potential to improve public service delivery. This undoubtedly presents the possibility of increased adoption of AI technologies by public sector organisations in delivering public services. Integrating AI technologies into the delivery of public services can significantly enhance efficiency and productivity (Yang 2022:2), improve accuracy and precision (Meroueh & Chen 2023:32), solve environmental challenges (Fu, Li & Chen 2023:11), enhance fraud detection and security (Choi & Lee 2018:13), and enable personalisation and customisation of public services based on individual preferences and needs (Hermann 2022:1262).

The results of Uganda's information and communications technology (ICT) status in the MDAs present positive indicators of its technological embracement in the delivery of public services. With all MDAs accessing the Internet, 97.9% had functional computers and laptops, 97.9% owned institutional websites and 94.7% provided institutional emails to their staff, illustrating a significant opportunity in the 4IR era. Despite having only 86.3% and 87.4% of the MDAs using their official websites and emails, respectively, to deliver public services and 28.4% using mobile applications, government technology goodwill is evident. To leverage AI technologies, it is important for MDAs to embrace cloud computing services to harness collaboration and communication across agencies and enhance data security, accessibility, scalability and flexibility. The results indicated that 64.2% of MDAs in Uganda embrace cloud computing services and 54.1% of them were hosted in government data centres. Social media is a good tool for governments to disseminate information to the public, and the results revealed that Twitter was the most preferred platform by MDAs (91.6%) followed by Facebook (82.1%).

The results aforementioned show that 21% of the MDAs were taking steps towards integrating 4IR technologies to deliver public services. However, the study found that only six MDAs had integrated AI technologies for delivering public services. The results revealed that MDAs in Uganda use AI technologies for customer queue management at UIA, revenue collection at URA, weather predictions and modelling by UNMA, reliable electricity transmission at UETCL, efficient electricity distribution at UEDCL and air quality management at KCCA.

As the study results have established, integrating AI technologies in customer queue management assists governments and public service providers in streamlining processes, improving customer experience and optimising resource allocation. Prior to the implementation of the AI system at UIA, citizens would be physically queuing to receive the services, uncertain of the duration it would take them to receive the needed services. With the AI-powered queue management system capabilities, historical data and real-time information can be analysed and predictions made for the lengths and waiting times. Availing the estimated waiting times to the citizens assists in reducing the uncertainty and frustration, thereby leading to their overall better experience.

The AI-powered queue management systems at the UIA have the ability to continuously monitor queue data and adjust the required resources accordingly. For example, areas that experience high demand can be noted in real time; therefore, available staff with the required resources can be allocated in real time, thus optimising service efficiency and minimising waiting times. Li et al. (2022:419) proposed that healthcare systems have employed similar queue AI management tools to enhance patient flow. These tools provide valuable information, such as the number of patients in the waiting room. Artificial intelligence-powered queuing systems have been used in healthcare to identify appropriate medical personnel, staffing levels and resource allocation (Li et al. 2022:419). Integrating AI-powered queuing systems can decrease congestion, delays and patient waiting times in healthcare institutions, thereby improving the efficiency of the healthcare system (Li et al. 2022:419).

Integrating AI technologies at URA in revenue collection, as reported in the results, has significantly improved the agency's overall operations and service provision. Artificial intelligence-powered revenue systems are capable of automating the processing of financial data such as tax returns and payments, thereby reducing the burden on human staff and minimising manual errors in data processing (Choi & Lee 2018:13). Irregularities such as non-compliance and potential tax evasion can be analysed using AI-powered revenue systems, thus alerting tax authorities to take proactive measures to ensure compliance and collect owed taxes (Soled & Thamas 2022:683). The instantaneous alerts and responses yield a reduction in the overall compliance expenses, thus resulting in increased revenue generation for public services (Soled & Thamas 2022:689).

The results revealed that AI technology integration in weather predictions and modelling by the UNMA improved the accuracy and timeliness of reliable weather forecasts. Artificial intelligence-powered weather systems can provide early warnings and alerts to public authorities and citizens in the event of predicted weather events, such as storms, floods and heat waves. Early warnings and alerts can be used to take proactive measures to mitigate potential risks, mobilise response resources and effectively allocate emergency resources. Weather predictions of AI-powered weather systems can also benefit communities in planning for agricultural activities by providing insights into the optimal planting times, irrigation schedules and pest control measures. Overall, integrating AI technologies into weather management systems can assist in developing climatic resilience strategies for public infrastructure and communities (Bochenek & Ustrnul 2022:11).

The results of the use of AI technologies in the management of electricity transmission by the UETCL report that the overall efficiency, reliability and sustainability of the energy sector were enhanced. The AI-powered sensors monitor and the data analytics analyse real-time data from the electricity infrastructure. Electricity transmission involves dangerous operations that are hazardous to humans and can lead to economic risk. Artificial intelligence tools that work as preventive measures to detect real-time potential equipment failures and faults are significant life- and economic-saving techniques (Richter et al. 2022:5). The capability of an AI system to predict faults or failures before they cause outages reduces downtime and enhances the reliability of the electricity supply (Richter et al. 2022:5). Insights provided by AI analytics into energy consumption patterns, grid performance and environmental impacts can be used by policymakers to develop informed energy policies and make evidence-based decisions.

In the distribution of electricity in Uganda, the results show that UEDCL integrated AI technologies into electricity management systems. Artificial intelligence-powered sensors or smart meters can analyse real-time data on electricity consumption patterns, demand fluctuations and equipment failure. This assists in preventing overloading or underutilisation of the grid, minimising service disruptions and hence improving the overall energy efficiency and reliability (Richter et al. 2022:6). An AI-powered meter system has dynamic pricing models that can adjust electricity rates based on real-time supply conditions and detect unusual consumption patterns. These unusual patterns may indicate energy theft or meter tampering, which can prompt service providers to take appropriate actions to prevent revenue losses. Therefore, AI technologies can enable electricity distribution agencies to monitor, analyse and control the electricity networks in real time (Richter et al. 2022:13). These capabilities result in more reliable, cost-effective and sustainable delivery of public services in the electricity sector.

The capabilities of AI technologies to improve the air quality in the environment are described in the aforementioned results. Kampala Capital City Authority uses AI-powered sensors and monitoring devices to continuously collect and analyse real-time air quality data in Kampala City. Fu et al. (2023:1) confirmed that AI technologies enhance environmental conditions and improve environmental governance when scientific data and accurate environmental ideas are used. Early warnings on pollution spikes or hazardous conditions provided by the AI-powered system to the authorities and the public could be used to take preventive actions and prevent pollution risks (Fu et al. 2023:2). The insights provided by AI algorithms upon analysing the data on pollution sources and factors affecting air quality can be used as evidence by authorities to allocate resources to areas with the greatest impact. Artificial intelligence technologies can, therefore, support policymakers in making data-driven decisions to form new measures to improve air quality.

The transformative capabilities and potential of AI technologies to improve public service delivery in Uganda and across the world are undeniable. However, the government must embrace them thoughtfully, acknowledging and addressing the associated challenges to advance public interest. Collaboration between policymakers, technology

experts and stakeholders is required to develop robust governance frameworks and accountability mechanisms.

The challenges related to data privacy, security, transparency and potential biases in AI algorithms must be addressed. Artificial intelligence systems require large amounts of data to train and operate effectively, and therefore, issues regarding the privacy of the individual data whose information is being processed raise concerns. This is because public services collect sensitive and personal information, such as financial data and individual biographies. Governments must have strict privacy regulations to protect the confidentiality of public sensitive and personal information before using it for AI training. Efforts to anonymise the data to obfuscate identifiable information from datasets before they are used for AI system training and analysis must be ensured.

The potential bias in Al algorithms, which arises from the biases in its historical data, must be considered to prevent unfair outcomes. This bias could exist in marginalised groups within a society, whose data were not considered in the design and training of AI systems. Addressing these AI algorithmic biases requires constant monitoring, auditing and establishment of ethical guidelines for AI implementation.

Similar to other computer applications, AI systems are also vulnerable to cyber-security threats, such as hacking, malware and ransomware attacks. The results revealed that 59% of the MDAs reported experiencing cybersecurity incidents during the past 12 months. Therefore, using AI in public services requires governments to ensure that the collected data are stored securely with appropriate robust safeguards to prevent data breaches.

Considering that AI systems often involve data sharing across agencies and departments, the risks of data exposure and unauthorised access are high. Therefore, the government needs robust data-sharing agreements and protocols to protect citizens' information. Adherence to ethical principles such as consent must be considered in the deployment of AI systems by government agencies (Fagan 2023). To avoid potential legal issues and fines, the data handling agreements, protocols and practices must be shared.

The governance challenges associated with citizens' access to the Internet, ICT devices and technical skills call for thoughtful considerations to minimise the digital divide of AI-driven services in the country. The results indicated that all MDAs in Uganda had access to the Internet and 97.9% of them had functional computers and laptops at their offices. Ministries, Departments and Agencies' access to the Internet and the ICT devices did not necessarily imply that citizens did too. The citizens' access to the Internet and/or digital literacy can vary according to their demographics. With no intentional strategies in place, the government's implementation of AI-driven services could limit the access of economically disadvantaged citizens and areas thereby exacerbating existing inequalities.

However, the study evidence from KCCA on how AI technology is used to manage pollution in Kampala, for accurate weather predictions by UNMA, and Umeme using a smart grid in electricity sales reveals the potential of AI technologies to improve service delivery in Uganda. Therefore, this study recommends the application of AI technologies in the agricultural sector, the economic backbone of the country to enhance productivity and resource management through crop yield prediction (Westergren et al. 2019). Artificial intelligence technologies can also be used to detect and manage malfunctions in an irrigation system, thereby preventing the overwatering of plants and minimising water waste. Artificial intelligence technologies can also be considered for pollution control and facility management in other urban areas of Uganda across various sectors. The technologies can be adopted for the detection and prevention of hazards, such as fires, chemical exposure, severe weather conditions and electric dangers. Artificial intelligence technologies can also be adopted in Uganda's transportation systems to collect valuable insights on traffic data and freight movements, make safety warnings, provide parking, reduce car accidents and theft, et cetera, thereby improving the overall transportation system in Uganda (Fagan 2023).

The Government of Uganda can also consider using AI technologies to improve healthcare services. With evidence from the US and Rwandan governments, AI technologies can be used to collect and analyse patient data from multiple sources for faster health decisions by physicians, as well as timely patient health monitoring. The successful integration of AI-powered chatbots and virtual assistants in Rwandan Healthcare to provide tele-medical information and services to citizens of Rwanda can also be considered to improve Uganda's public service delivery in various sectors (Schenker 2021). The study recommends the integration of AI-powered chatbots in all public services to provide personalised assistance and support to citizens as well as offer quick and accurate responses to public queries and concerns (Schenker 2021).

Notably, the implementation and maintenance of AI systems require a given set of skills and expertise (Misuraca & Noordt 2020). Outsourcing is not a bad management practice; however, outsourcing a core activity in management and governance can produce undesired results or a disaster. It is of great importance that governments not only consume or adopt AI technologies in their operations but also be in a position to invest in citizens to design and develop standard AI products and services to enhance public service delivery. Consequently, embracing AI technologies can result in job displacements in certain niches and sectors (Misuraca & Noordt 2020). To strike a fair balance, the government must strategise to up-skill or re-skill the workforce to prepare the citizens for the changing job landscape (Fagan 2023).

In summary, embracing AI technologies responsibly and proactively in public service delivery presents a transformative opportunity for the government of Uganda to overcome

traditional public service barriers. Leveraging AI technologies can create citizen-centric, efficient, transparent and accountable governance systems. However, the government must undertake deliberate planning, prioritise privacy by design, implement strong data protection policies, conduct regular AI security audits and involve relevant stakeholders in the decision-making process.

Conclusion

Artificial intelligence technologies have boundless potential to transform public service delivery and benefit humanity as a whole in ways beyond current expectations. Given the evidence presented in this article regarding the transformative effects of AI technologies on public service delivery in Uganda, it is clear that there is great potential to utilise AI even further. This would result in the creation of an efficient, transparent and citizen-centric public service ecosystem. However, deliberate approaches by governments must be taken to address governance challenges, mitigate data privacy issues and ethical concerns during AI implementation (development and deployment), and ensure stakeholder collaboration to harness the full potential of AI in public service delivery.

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Authors' contributions

T.N. framed the conceptualisation, methodology, data collection and analysis, and writing the original draft and editing. D.E.U. assisted in the conceptualisation, methodology, validation of the study, provision of financial resources, reviewing the manuscript and overall supervision of the study.

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Data availability

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