

RESEARCH REPORT

Leveraging cloud computing for improved health service delivery: Findings from public health facilities in Kisumu County, Western Kenya-2019

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Abstract

Introduction: Healthcare delivery systems across the world have been shown to fall short of the ideals of being cost-effective and meeting pre-established standards of quality but the problem is more pronounced in Africa. Cloud computing emerges as a platform healthcare institutions could leverage to address these shortfalls. The aim of this study was to establish the extent of cloud computing adoption and its influence on health service delivery by public health facilities in Kisumu County.

Methods: The study employed a cross-sectional study design in one-time data collection among facility in-charges and health records officers from 57 public health facilities. The target population was 114 healthcare personnel and the sample size ($n = 88$) was computed using Yamane formula and drawn using stratified random sampling. Poisson regression was used to determine the influence of cloud computing adoption on the number of realized benefits to health service delivery.

Results: Among 80 respondents, Cloud computing had been adopted by 42 (53%) while Software-as-a-Service, Platform-as-a-Service and Infrastructure-as-a-Service implementations were at 100%, 0% and 5% among adopters, respectively. Overall, those who had adopted cloud computing realized a significantly higher number of benefits to health service delivery compared to those who had not (Incident-rate ratio (IRR) = 1.93, 95% confidence interval (95% CI) [1.36-2.72]). A significantly higher number of benefits was realized by those who had implemented Infrastructure-as-a-Service alongside Software-as-a-Service (IRR = 2.22, 95% CI [1.15-4.29]) and those who had implemented Software-as-a-Service only (IRR = 1.89, 95% CI [1.33-2.70]) compared to non-adopters. We observed similar results in the stratified analysis looking at economic, operational, and functional benefits to health service delivery.

Conclusion: Cloud computing resulted in improved health service delivery with these benefits still being realized irrespective of the service implementation model deployed. The findings buttress the need for healthcare institutions to adopt cloud

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computing and integrate it in their operations in order to improve health service delivery.

KEYWORDS

benefits, cloud computing, health facilities, health service delivery, Kenya

1 | INTRODUCTION

Cloud computing is defined as a model for enabling ubiquitous, expedient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction.¹ Cloud computing is offered using three standard models: Software-as-a-Service (SaaS) which entails the consumer using provider applications over a cloud infrastructure through either a program interface or a client interface like a web browser; Platform-as-a-Service (PaaS) which involves a service provider offering access to a cloud-based environment over which consumers can build and deliver applications with the provider managing the underlying infrastructure; Infrastructure-as-a-Service (IaaS) where the consumer rents processing, storage, networks, and other computing resources over which they can deploy and run software like operating systems and applications.² Cloud computing offers healthcare organizations an array of benefits; economic, operational, and functional benefits.³ The economic benefits of cloud computing include less capital expenditure, lower maintenance cost, reduced IT labor costs, and energy savings. The operational benefits include unlimited computing resources, enhanced collaboration, a 24 hour platform and improved security. Lastly, functional benefits are wider variety of services and the potential for broad interoperability and integration. Cloud computing phenomenon is drastically shaking the waters of change in the information technological environment and has emerged as a major technological innovation across industries to reduce IT costs, foster collaboration while increasing service delivery.^{4,5}

The health care delivery in both high-income countries and low- and middle-income countries has been shown to fall short of the ideals⁶ of the citizens receiving healthcare services whenever needed and the health services being cost-effective and meeting pre-established standards of quality according.⁷ However, the problem is more pronounced in Africa with only 50% of its populace having access to modern health care facilities and most countries spend less than 10% of their gross domestic product (GDP) on healthcare.^{8,9} Technology has been proposed as one of the solutions that can be embraced to bridge this gap in health service delivery.¹⁰ Most health facilities in the county (57%) have not integrated technology in their operations and patient information is still captured using patient books and hard copy forms¹¹ and as a result health service delivery still suffers from increased human errors, poor clinical outcomes, poor care coordination, practice inefficiencies, no tracking of data over time, limited collaboration, and high financial costs.¹² Cloud computing, due to its inherent characteristics and benefits, is an effective

platform that healthcare organizations can leverage to improve health service delivery. The determinants of cloud computing adoption in this setting have been reported elsewhere¹³ and this paper focused on establishing the extent of cloud computing adoption and its influence on health service delivery by public health facilities in Kisumu County.

2 | QUESTION OF INTEREST

What is the influence of cloud computing and the various service implementations models on health service delivery by public health facilities in Kisumu County, Kenya?

3 | METHODS

3.1 | Study setting

This study was conducted in Kisumu County located in Western Kenya by the shores of Lake Victoria and it has under its jurisdiction 57 public health facilities run by the Ministry of Health: Level 3-Health centers are run by a clinical officer as the facility-in-charge and provide comprehensive primary care (n = 34); Level 4 Sub-county hospitals are managed by a medical superintendent and offer comprehensive medical and surgical services. (n = 22); Level 5 County referral hospital which is the referral point for the sub-county hospitals and offer specialized care (n = 1).¹⁴ Kisumu is plagued with high burden of disease: child mortality (infant mortality rate: 95 per 1000 live births; under five mortality rate: 149 per 1000 live births), HIV/acquired immune deficiency syndrome prevalence (16.3%), and malaria prevalence (under five:27.0%; ≥5; 20.7%).^{15,16}

3.2 | Study design and population

The study used a cross-sectional study design that entailed a one-time collection of data from sampled healthcare personnel in public health facilities in Kisumu County using questionnaire (shown in Supplement 1). The target population for this study was 114 healthcare personnel from 57 public health facilities. They were facility in-charges and health records information officers in Level 3 to Level 5 public health facilities in Kisumu County, Kenya. Facility in-charges were considered for inclusion in this study because they are the decision-makers in the day to day running of the health facilities and would therefore have a say in the

adoption of cloud computing. Health records information officers were included in this study because they are the end-users of most health management information systems. In most facilities, they also doubled up as the IT personnel providing user support and maintenance of systems, they would therefore offer great technical insight. The samples size ($n = 88$) was calculated using Yamane formula¹⁷ for finite populations: a simplified formula for sample size calculation with the assumption of a 95% confidence level and $P = .05$ as shown below.

$$n = \frac{N}{1 + N(e)^2},$$

where the sample size is given by n , N represents the population size, and e stands for the level of precision.

$$N = 114; e = 0.05.$$

$$n = N / (1 + N(e)^2).$$

$$n = 114 / (1 + 114(0.05)^2).$$

$$n = 88.$$

The study used stratified random sampling method to draw the sample from the sampling frame based on the level of facilities. At enrolment information on the technological, organizational, and behavioral contexts as well as the cloud computing adoption status and realized benefits were collected.

3.3 | Inclusion and exclusion criteria

Healthcare personnel (facility in-charge and health records officer) in any public health facility in Level 3 to Level 5 were included in the study. Level 1 (Community) and Level 2 (Dispensaries) health facilities were not included in this study because they lacked the requisite technological infrastructure, installed network topologies and enterprise systems, upon which cloud computing can be deployed. The exclusion criteria for this study involved excluding public health facilities (Level 3-Level 5) that did not have a health records information officer deployed in the facility.

3.4 | Data and statistical methods

Data analysis was done using Stata/SE 16.0 (StataCorp, College Station, Texas). Descriptive statistics were used to provide summaries about the sample and measures: we reported frequencies and proportions. We ran a Poisson regression model¹⁸ to determine the influence of cloud computing adoption on health service delivery. We ran four models in which the outcome variable was count data: overall benefits, economic benefits, operational benefits, and functional benefits. For the purposes of this study, the following definitions were used: Economic benefits were computed as the sum of “less capital expenditure,” “lower maintenance cost,” “reduced IT labor costs,” and “energy savings” benefits; operational benefits were computed as the sum of “unlimited computing resources,” “enhanced collaboration,” “a 24 hour platform,” and “improved security” benefits; functional

benefits were computed as the sum of “wider variety of services” and “interoperability and integration” benefits; lastly, overall benefits realized were computed as the sum of economic, operational, and functional benefits. The independent variables were cloud computing adoption and the service implementation models implemented. The results were presented as incident-rate ratios (IRR) and the 95% confidence intervals (95% CI).

3.5 | Ethical review

The study was conducted after the National Commission for Science, Technology and Innovation issued a research permit. An approval was also sought from the Kisumu County Department of Health to be able to conduct this study in public health facilities in the county and the director of health issued an approval letter. Participation in the study was voluntary and the scope of this study was explained to the healthcare personnel, the procedures involved, the potential benefits and the confidentiality of provided information. Consents were then sought from all potential respondents. The study was conducted under scientific integrity by adhering to professional values and practices when conducting the research and reporting the results of this study to ensure objectivity, clarity, and reproducibility.

3.6 | Results

During the study period, we enrolled 80 healthcare personnel from 40 public health facilities in Kisumu County and 42 (53%) of them had adopted cloud computing. Among those who had adopted cloud computing, 100% had implemented Software-as-a-Service (SaaS), 0% had implemented Platform-as-a-Service (PaaS), and 5% had implemented Infrastructure-as-a-Service (IaaS) (Figure 1). The most prevalent SaaS implementations were implementations done by the national government (national-level systems); Kenya Health Information System (KHIS) 100%, Health Facility Equipment Assessment Application (HEAA) 100%. Kenya Master Facility List (KMFL) and Health Workforce Information Systems (iHRIS) were used at the sub-county and county levels.

The individual benefits to health service delivery reported by public health facilities in this setting are shown in Figure 2. The most reported benefits of cloud computing adoption among adopters were improved security (90%), 24-hour platform (88%), and enhanced collaboration (81%) compared to 34%, 39%, and 37%, respectively, among those who non-adopters, enhanced collaboration included availability of monthly reports on KHIS as well as ease of sharing data with partner institution. While unlimited computing resources (40%), and wider variety of services (26%) and energy savings (17%) were the least reported benefits among adopters compared to 8%, 5%, and 0%, respectively, among non-adopters. The categorization of the benefits into economical, operational, and functional was not mutually exclusive: 36 (45%) reported all the three categories; 28 (35%) reported two benefits; 4 (5%) reported 1 benefit; 12 (15%) reported none.

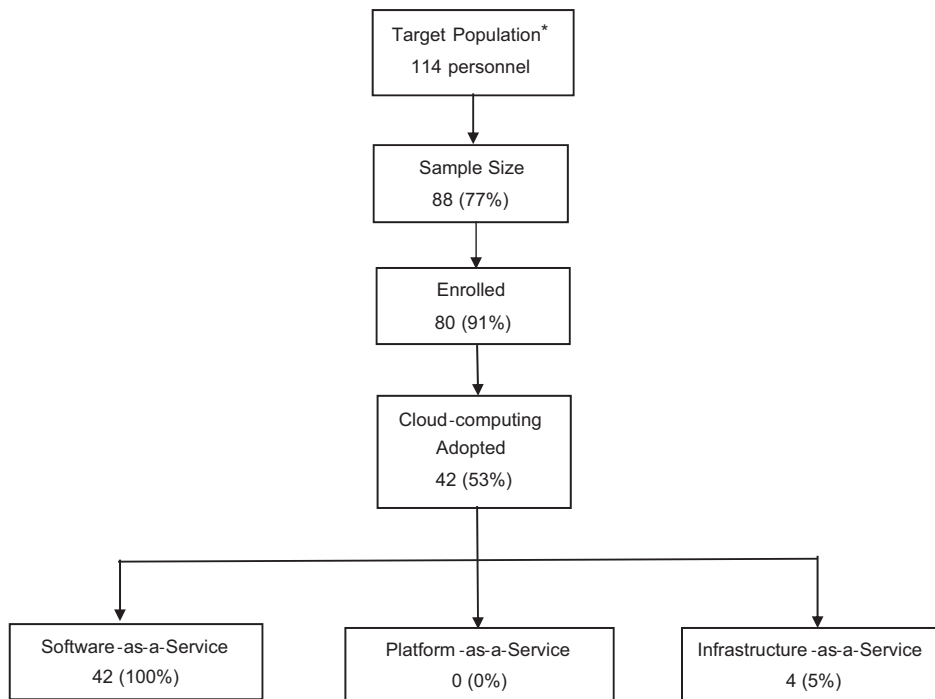


FIGURE 1 Cloud computing adoption by Public health facilities in Kisumu County, 2019. *Facility in-charges and health records officers

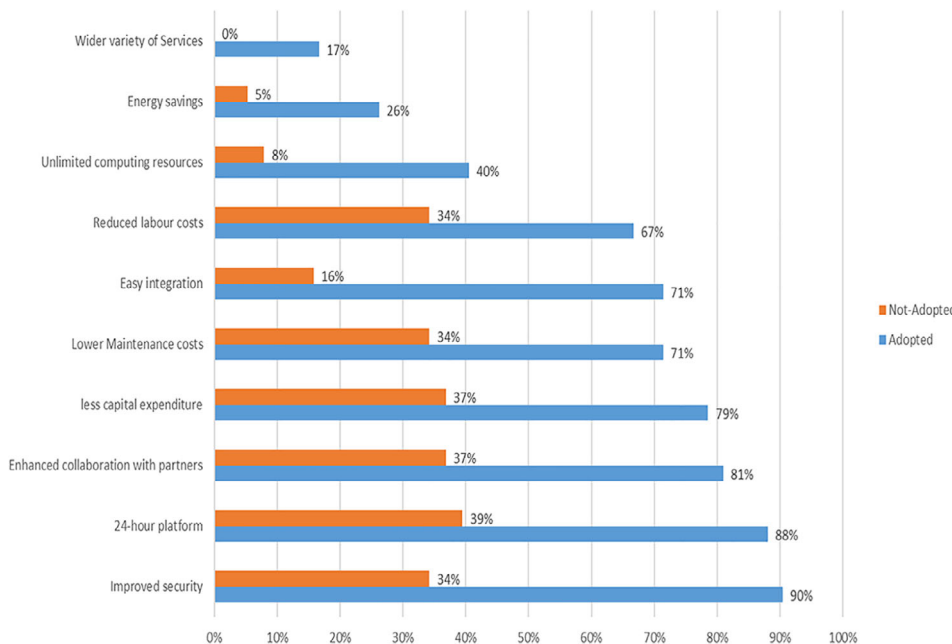


FIGURE 2 Cloud computing benefits to health service delivery among Public health facilities in Kisumu County, 2019

Overall, those who had adopted cloud computing realized a significantly higher number, 1.93 times, of benefits to health service delivery compared to those who had not (Incident-rate ratio (IRR) =1.93, 95% CI [1.36-2.72]). In addition, those who had implemented IaaS together with SaaS realized a significantly higher number, 2.2 times, of benefits to health service delivery compared to those who had not adopted cloud computing (IRR = 2.22, 95% CI [1.15-4.29]) while those who had implemented SaaS only realized a significantly higher number, 1.89 times, of benefits to health service delivery compared to those who had not adopted cloud computing (IRR = 1.89,

95% CI [1.33-2.70]) (Table 1). The number of benefits realized by those who had implemented IaaS alongside SaaS compared to those who had only implemented SaaS did not differ significantly (IRR = 1.17, 95% CI [0.63-2.20]).

Regarding economic benefits to health service delivery, those who had adopted cloud computing realized a significantly higher number, 2.2 times, of economic benefits to health service delivery compared to those who had not (IRR) =2.20, 95% CI [1.53-3.15]). In addition, those who had implemented IaaS together with SaaS realized a significantly higher number, 2.94 times, of economic benefits to

TABLE 1 Predicting overall number of benefits to health service delivery due to cloud computing adoption by Public health facilities in Kisumu County, 2019

	Number of benefits to health service delivery				Incident-rate ratio IRR [95%CI]	P-value
	0 (n = 12) n (%)	1-3 (n = 11) n (%)	4-6 (n = 35) n (%)	7-9 (n = 21) n (%)		
Cloud computing						
Not adopted	10 (83.3)	10 (90.9)	17 (48.6)	1 (4.6)	Ref	
Adopted	2 (16.7)	1 (9.1)	18 (51.4)	21 (95.5)	1.93 [1.36-2.72]	<.0001
Service implementations model						
None	10 (83.3)	10 (90.9)	17 (48.6)	1 (4.6)	Ref	-
Infrastructure-as-a-Service & Software-as-a-Service	0 (0.0)	0 (0.0)	1 (2.9)	3 (13.6)	2.22 [1.15-4.29]	.017
Software-as-a-Service	2 (16.7)	1 (9.1)	17 (48.6)	18 (81.8)	1.89 [1.33-2.70]	<.0001

Note: Bold values shows $p < 0.05$.

TABLE 2 Predicting number of economic benefits to health service delivery due to cloud computing adoption by Public health facilities in Kisumu County, 2019

	Number of economic benefits to health service delivery					Incident rate ratio IRR [95%CI]	P-value
	0 (n = 17) n (%)	1 (n = 13) n (%)	2 (n = 25) n (%)	3 (n = 19) n (%)	4 (n = 6) n (%)		
Cloud computing							
Not adopted	15 (88.2)	8 (61.5)	11 (44.0)	4 (21.1)	0 (0.0)	Ref	
Adopted	2 (11.8)	5 (38.5)	14 (56.0)	15 (78.9)	6 (100.0)	2.20 [1.53-3.15]	<.0001
Service implementations model							
None	15 (88.2)	8 (61.5)	11 (44.0)	4 (21.1)	0 (0.0)	Ref	-
Infrastructure-as-a-Service & Software-as-a-Service	0 (0.0)	0 (0.0)	0 (0.0)	3 (15.8)	1 (16.7)	2.94 [1.58-5.48]	.001
Software-as-a-Service	2 (11.8)	5 (38.5)	14 (56.0)	12 (63.2)	5 (83.3)	2.12 [1.47-3.06]	<.0001

TABLE 3 Predicting number of operational benefits to health service delivery due to cloud computing adoption by Public health facilities in Kisumu County, 2019

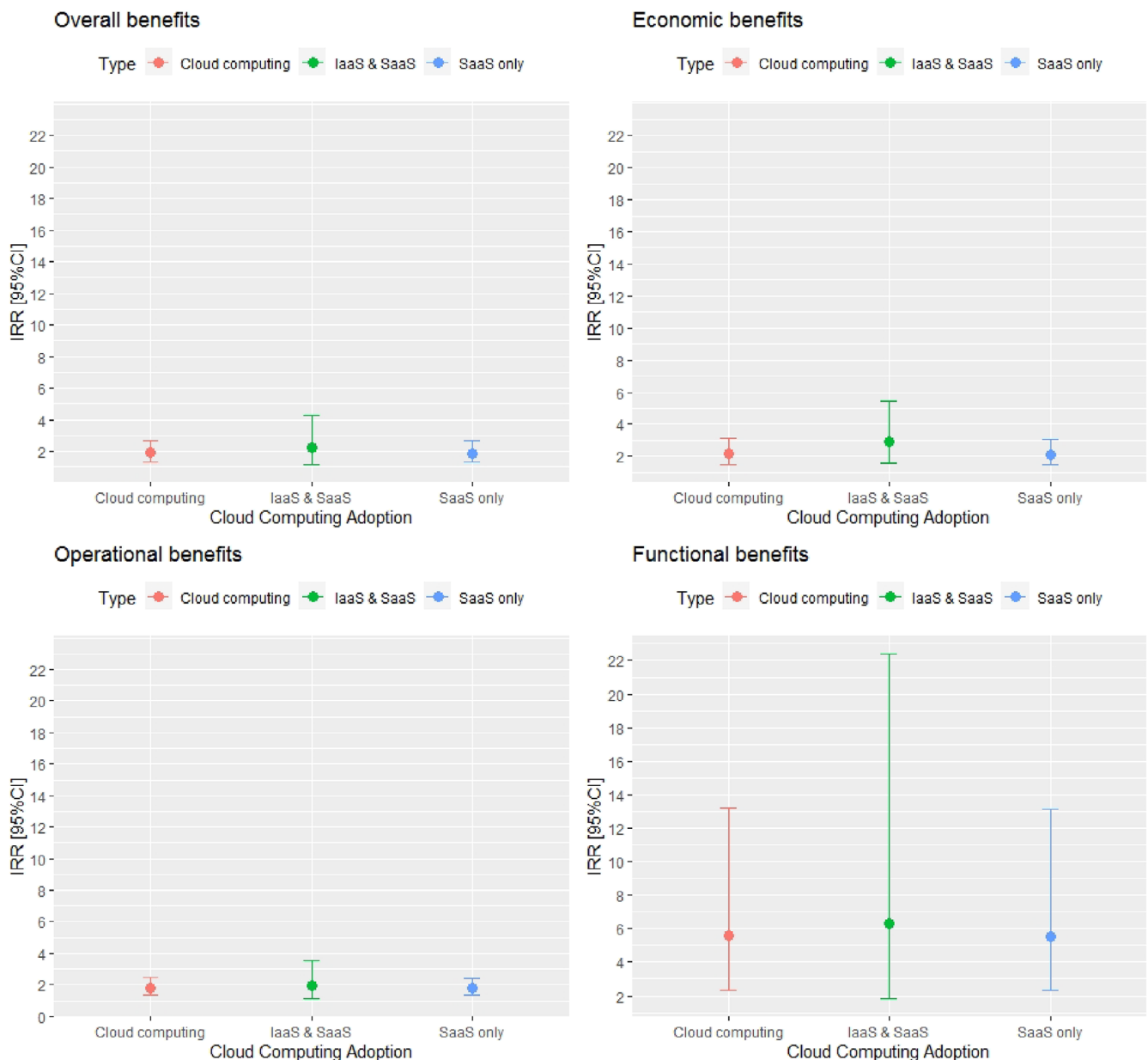
	Number of operational benefits to health service delivery					Incident-rate ratio IRR [95%CI]	P-value
	0 (n = 12) n (%)	1 (n = 5) n (%)	2 (n = 17) n (%)	3 (n = 34) n (%)	4 (n = 12) n (%)		
Cloud computing							
Not adopted	10 (83.3)	3 (60.0)	15 (88.2)	10 (29.4)	0 (0.0)	Ref	-
Adopted	2 (16.7)	2 (40.0)	2 (11.8)	24 (70.6)	12 (100.0)	1.81 [1.34-2.45]	<.0001
Service implementations model							
None	10 (83.3)	3 (60.0)	15 (88.2)	10 (29.4)	0 (0.0)	Ref	-
Infrastructure-as-a-Service & Software-as-a-Service	0 (0.0)	0 (0.0)	0 (0.0)	3 (8.8)	1 (8.3)	1.96 [1.08-3.56]	.027
Software-as-a-Service	2 (16.7)	2 (40.0)	2 (11.8)	21 (61.8)	11 (91.7)	1.79 [1.32-2.44]	<.0001

health service delivery compared to those who had not adopted cloud computing (IRR = 2.94, 95% CI [1.58-5.48]) while those who had implemented SaaS only realized a significantly higher number, 2.12

times, of economic benefits to health service delivery compared to those who had not adopted cloud computing (IRR = 2.12, 95% CI [1.47-3.06]) (Table 2). Additionally, the number of economic benefits

TABLE 4 Predicting number of functional benefits to health service delivery due to cloud computing adoption by Public health facilities in Kisumu County, 2019

	Number of functional benefits of health service delivery			Incident-rate ratio IRR [95%CI]	P-value
	0 (n = 42) n (%)	1 (n = 33) n (%)	2 (n = 5) n (%)		
Cloud computing					
Not adopted	32 (76.2)	6 (18.2)	0 (0.0)	Ref	-
Adopted	10 (23.8)	27 (81.8)	5 (100.0)	5.58 [2.35–13.22]	<.0001
Service implementations model					
None	32 (76.2)	6 (18.2)	0 (0.0)	Ref	-
Infrastructure-as-a-Service & Software-as-a-Service	1 (2.4)	2 (6.1)	1 (20.0)	6.33 [1.79–22.4]	.004
Software-as-a-Service	9 (21.4)	25 (75.8)	4 (80.0)	5.50 [2.30–13.13]	<.0001

**FIGURE 3** Estimated incident-rate ratios of benefits to health service delivery due to cloud-computing adoption by Public health facilities in Kisumu County, 2019

realized by those who had implemented IaaS alongside SaaS compared to those who had implemented only SaaS did not differ significantly (IRR = 1.39, 95% CI [0.78-2.48]).

Regarding operational benefits to health service delivery, those who had adopted cloud computing realized a significantly higher number of benefits, 1.81 times, to health service delivery compared to those who had not (IRR = 1.81, 95% CI [1.34-2.45]). In addition, those who had implemented IaaS alongside SaaS realized a significantly higher number, 1.96 times, of operational benefits to health service delivery compared to those who had not adopted cloud computing (IRR = 1.96, 95% CI [1.08-3.56]) while those who had implemented SaaS only realized a significantly higher number, 1.79 times, of operational benefits to health service delivery compared to those who had not adopted cloud computing (IRR = 1.79, 95% CI [1.32-2.44]) (Table 3). Additionally, the number of operational benefits realized by those who had implemented IaaS alongside SaaS compared to those who had implemented only SaaS did not differ significantly (IRR = 1.09, 95% CI [0.62-1.94]).

Lastly, regarding functional benefits to health service delivery, those who had adopted cloud computing realized a significantly higher number, 5.58 times, of benefits to health service delivery compared to those who had not (IRR = 5.58, 95% CI [2.35-13.22]). In addition, those who had implemented IaaS together with SaaS realized a significantly higher number, 6.33 times, of functional benefits to health service delivery compared to those who had not adopted cloud computing (IRR = 6.33, 95% CI [1.79-22.40]) while those who had implemented SaaS only were realized a significantly higher number, 5.5 times, of functional benefits to health service delivery compared to those who had not adopted cloud computing (IRR = 5.50, 95% CI [2.30-13.13]) (Table 4). Additionally, the number of functional benefits realized by those who had implemented IaaS alongside SaaS compared to those who had implemented only SaaS did not differ significantly (IRR = 1.15, 95% CI [0.41-3.25]). Figure 3 shows a visual presentation of the IRR from the four models reported above.

4 | DISCUSSION

This study aimed to establish the extent of cloud computing adoption and the service implementations models deployed and their effect on health service delivery by public health facilities in Kisumu County. Our most important findings are summarized as follows: First, there was an improved adoption of cloud computing by public health facilities and SaaS was the most prevalent service implementation model. Second, those who had adopted cloud computing realized a significantly higher number of overall benefits to health service delivery compared to those who had not adopted. Third, in terms of service implementations models, those who had implemented IaaS together with SaaS and those who had implemented only SaaS realized a significantly higher number of overall benefits to health service delivery compared to those who had not adopted cloud computing. Lastly, looking at economic, operational, and functional benefits to health service delivery separately, those who had adopted cloud computing

realized a significantly higher number of benefits in all the three categories compared to those who had not adopted cloud computing. Furthermore, those who had implemented IaaS together with SaaS and those who had implemented only SaaS realized a significantly higher number of benefits to health service delivery in all the three categories compared to those who had not adopted cloud computing.

The study found out that the prevalence of cloud computing in public health facilities was 53% shown in Figure 1. This is an improvement compared to 35.6% that was reported previously among public sector institutions.¹⁹ This increase can be attributed to a high ratio of internet users connecting with mobile devices compared to traditional fixed-point connections²⁰ as a study on the impact of internet connectivity in Kenya found out that 99% of internet users access the internet through mobile phones and mobile devices.²¹

In terms of cloud service models, SaaS was the most prevalent model while very few had implemented IaaS and there were no implementations of PaaS (0%) in this setting as shown in Figure 1. This differential in implementation of cloud service models could be attributed to high cost implications (the cost of cloud computing reduces the higher up the cloud stack you go; SaaS is cheaper than PaaS and PaaS is Cheaper than IaaS) and the level of skills required to implement and maintain services associated with PaaS and IaaS.^{22,23} Lack of implementation of PaaS service model can be explained by the fact that most public health facilities rely on national-level systems that are developed and maintained by the Ministry of Health. Furthermore, health facilities that have adopted other digital health systems in addition to the nation-level systems normally outsource the development and testing of such systems or rely on partner institutions. It is also important to note that the 5% of facilities that had implemented both SaaS and IaaS were the largest hospitals in terms of scope of operations and bed-capacity and can possibly be explained by firm size being a major factor affecting adoption of new technology and it acts as resilience for environmental shocks.²⁴ Bigger enterprises have extra resources that motivate the adoption of technological innovations. The uptake of internet and its infrastructures in business is slower in smaller firms than in larger firms indicating that financial constraints, lack of professional expertise, and short-term management perspectives are characteristics of small business.²⁵

Our study demonstrated that those who had adopted cloud computing realized a higher number of overall benefits to health service delivery compared to those who had not adopted. This is consistent with the findings from other studies that have shown that cloud computing would positively impact health care services.^{3,26-28} These results can be explained by the fact that cloud computing because of its inherent characteristics²⁹ and benefits emerges as an effective platform to improve health service delivery. The essential characteristics of *on-demand self-service* ensured that clients got services in a timely manner with minimal provider interactions thereby reducing the time it took to provide care by healthcare personnel and this bolsters the delivery of health services in line with World Health Organization's (WHO) requirement of ideal health service delivery. The essential characteristic of *rapid elasticity* ensured that the computing resources available to the caregivers was unlimited and as such they

offered care without suffering from technological limitations and this ensured health services were available when needed leading to improved health service delivery. The availability of unlimited computing resources, also offered healthcare givers who are off-site the opportunity to remotely offer consultation, read x-rays and offer other services ensuring care is available when needed further improving access to care beyond traditional confines of the hospital set-up. The digitization of health management information systems in order to benefit from cloud computing further mitigates against human errors that are more frequent in an analog setup and it also reduces poor clinical outcomes as care is readily available and offered in a timely manner and remotely if need be.

The essential characteristics of *Measured Service* also ensured that caregivers who had adopted cloud computing only payed for what they used and shifted from heavy capital expenditure. These findings are in concurrence with results from previous studies.³⁰⁻³² These findings can possibly be explained by the fact that cloud computing is a pay per use platform and organizations only pay for what they use and as a result, there is less capital expenditure. The cloud provider is also in charge of the maintenance of all computing resources as well as the administration and securing of the entire cloud eco-systems. Consequently, there is lower maintenance costs, reduced IT labor costs and energy savings translating into reduced operation costs making healthcare institutions cost-effective in the delivery of health services thereby improving health service delivery. The cloud computing has also been shown^{33,34} to enhance collaboration consistent with findings from our study. This can be explained by the fact that cloud computing offered enhanced collaboration as data were stored remotely thereby mitigating against geographical barriers while providing faster and secure access to shared data. It was also possible for reports to be downloaded directly from the KHIS platform thereby allowing easy access to reports and to tracking of data overtime whilst reducing human errors in the compilation of reports and practice inefficiencies. In addition, cloud computing had improved security compared to traditional information systems as it had sophisticated security controls that included data encryption and secured access login. Cloud providers also were able to engage skilled cyber-security experts to secure the entire eco-system.

Lastly, previous studies have shown that cloud computing offers a wider variety of services.^{35,36} Cloud computing offers access to a larger ecosystem of healthcare providers, payer, life sciences, and technological solution partners was offered by cloud computing and this increased the potential for a wide range of services to healthcare institutions thereby bolstering health service delivery in this setting. For example, the integration of mobile money payments in HMIS makes it convenient and easy for care seekers to pay their bills and access services. Furthermore, cloud-computing services in healthcare are internet based and usually use standard protocols, so connecting them to other systems and applications is typically straightforward. However, Electronic Medical Records (EMR) vendor contractual and technical impediments still present challenges; technical and legal agreements still make it complicated to integrate with EMR systems.³

All these taken together explain why those who had adopted cloud computing realized a significantly higher number of overall benefits to health service delivery in this setting compared to non-adopters. It further explains why similar results were seen in all the three categories; economical, operational, and functional. Our findings also indicate that irrespective of the service implementation model deployed, organizations still realized a significantly higher number of benefits to health service delivery using IaaS together with SaaS or SaaS only.³⁷ It has been shown that each cloud computing service implementation model offers unique features and functionalities, organizations should therefore not worry whether they would realize the expected business value from adopting a given cloud service model but they should instead understand their needs and acquire cloud models that would best address them.

5 | LIMITATION

The study was limited by a small sample size as we were only able to successfully collect data from 90% of the sample and this may hinder the generalizability of our findings.

6 | CONCLUSION

We observed that cloud computing resulted in improved health service delivery with these benefits still being realized irrespective of the service implementation model deployed. Findings from our study buttress the need for healthcare institutions to adopt cloud computing and integrate it in their operations to realize improved health service delivery. Furthermore, majority of SaaS implementations in this setting being national-level systems, there still exists great potential for healthcare institutions to leverage cloud computing by adopting bottom-up cloud systems that are unique to their needs and thereby realize even greater benefits translating to improved health service delivery.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, Billy Ogwel, George Odhiambo-Otieno, and Gabriel Otieno; *Methodology*, Billy Ogwel, George Odhiambo-Otieno, and Gabriel Otieno; *data analysis*, Billy Ogwel; *Writing—Original Draft Preparation*; Billy Ogwel; *Writing—Review and Editing*, George Odhiambo-

Otieno, Gabriel Otieno, James Abila, and Richard Omore; *supervision*, George Odhiambo-Otieno, and Gabriel Otieno. All authors have read and agreed to the published version of the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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