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ORIGINAL RESEARCH

Conceptualizing a Model for Cloud-Based Hospital Management Systems for the South African Public Health Sector

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A – Study design;
B – Data collection;
C – Statistical analysis;
D – Data interpretation;
E – Manuscript preparation;
F – Literature search;
G – Funds collection

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Abstract

Background and Aim of Study: *Real-time access of information in the healthcare environment is essential, as it not only helps medical personnel to have adequate and timely information, but it also assists patients to be served more easily. Hospitals in rural areas are operating at a low bandwidth and have poor IT infrastructure that causes intermittent networks leading to disruptions and slow service delivery. This necessitates the Hospital Management System (HMS) to be deployed in the cloud environment to reduce the challenges leading to poor service delivery.*
The aim of the study: to develop a model for cloud-based HMS for the South African public health sector.

Material and Methods: *This study identified three public district municipality hospitals in Gauteng Province, South Africa, that were already using HMS and used them for data collection. Each hospital had up to 50 healthcare workers, and this formed the population of 150 from the three hospitals, from which a sample size of 108 respondents was selected. Data were collected using a closed-ended questionnaire and analyzed quantitatively using SPSS v25.*

Results: *The results demonstrated that the suggested model has a good prediction power of 60.9% (R^2=0.609) and that with the exception of environmental aspects, the rest of the constructs has a significant contribution to the successful implementation of the cloud-based HMS. Social aspects had the highest prediction power of 60.0% (β=0.600) at p=0.001; followed by risk analysis and control with 41.3% (β=0.413) at p=0.009. On the other hand, environmental aspects had the least and non-significant prediction of 12.3%.*

Conclusions: *This study contributes to the ongoing call to have seamless healthcare provision systems. The model developed in this study extends the research of modernizing healthcare provision by leveraging technological innovations.*

Keywords: *cloud computing, hospital management systems, healthcare, public, South Africa*

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Introduction

Information and communication technology (ICT) is universally regarded as a vital tool for improving business competitiveness and economic growth of a country as it has the potential to improve the quality, safety, and efficiency of service delivery. Generally, there is a consensus that ICT has significant effects on the productivity of firms, but these effects can only be realized if, and when, ICTs are widely spread and used efficiently.

ICT has the ability to help people collect, store, manage, and distribute knowledge. For instance, in the healthcare domain the use of information technology (IT) has improved communication between medical personnel and patients (Djock, 2023). Previously, patients would queue for hours to get help in hospitals as everything was done manually. This trend has, however, changed with the increasing use of automated healthcare systems such as Hospital Management Systems (HMS) that have increased the speed at which patients' information is accessed and retrieved (Khan et al., 2014). The use of IT and its application has propelled developments that have improved service delivery in all sectors, inclusive of public health. Recent developments in remote healthcare systems have witnessed significant interest from the IT industry, which provides universal and easily deployable healthcare systems (Djock, 2023; Profetto et al., 2022).

Katuu (2018) asserts that well-formed hospital management workflows involve important decision-making that should be done efficiently and quickly. Katuu (2018) indicates that it is becoming difficult in many health sector facilities to improve efficiency without the use of HMS. The HMS assists in the handling of the different directions of hospital workflows, and it helps in managing smooth healthcare performance along with administrative, medical, legal, and financial control (Djock, 2023). Further still, HMS is essential in managing automated operations of the hospital, using radio frequency identification (RFID) tags to secure access (Profetto et al., 2022).

The aim of the study. To develop a model that informs the deployment of the Hospital Management Systems within the cloud.

To realize the research goal, the following objectives were set to be achieved: to determine factors that influence cloud-based HMS implementation, to determine the extent of cloud-based HMS integration in the South African health institutions and also rank and use the identified factors for the development of a cloud-based HMS model for the South African health sector.

Materials and Methods

This study followed a quantitative research approach. The study used close-ended questionnaires to collect data. Due to increased restrictions of visitations at many institutions, data was collected online. The questionnaire with close-ended questions was uploaded onto Survey Monkey and the link leading to the survey was sent to the contact person to distribute to the respondents. At each hospital, the researcher got a contact person, mostly from the ICT directorate. For anonymity, the questionnaire on the Survey Monkey was designed in such a way that respondents only needed to click on the submission button and the filled questionnaire was captured on Survey Monkey database with the respondents' particulars on completion of the questionnaire, the filled datasets were exported to the Statistical Package for Social Scientists (SPSS v25) for analysis. The questionnaire was designed in such a way that neither the particulars of the individual respondents nor those of the health institution were asked, so anonymity was ensured. After data had been captured on the Survey Monkey database, the questionnaire was exported to SPSS. However, for easy analysis the questionnaire was coded in such a way that the constructs and their attributes are shorted to carry meaning while observing originality of the question item and the construct.

The population of this study was health personnel in public hospitals that are using HMS in Gauteng Province, South Africa. This study identified three public hospitals that were already using HMS. According to Massyn et al.'s (2020) report, South African hospitals are human resource constrained and on average, there are between 30 to 50 medical personnel and health workers in district hospitals and slightly more numbers in provincial hospitals. Hence, the population of the study based on the district hospital level was 150 respondents.

By using the Krejice and Morgan's tool for determining the sample size of a finite population, the derived sample size for this study was 108. Based on this sample size, a total of 130 survey links were distributed and out of this 98 completed questionnaires were returned though 83 were usable.

Research is conducted to collect relevant information that can be used to solve the identified research problem (Babbie, 2016). Hence, a high level of reliability and validity should be maintained when collecting data. Additionally, the measuring instrument must be designed such that it consistently measures what it is supposed to measure, and research should ensure that while collecting data, the obtained results are trustworthy in order to develop future forecasts (Yin, 2014). Research standards are based on credibility, reliability, and conformity of data hence validity and reliability must be ensured for the quality and research standards.

Reliability refers to the measuring instrument's capacity to produce similar results with duplicated or replicated tests (Yin, 2014).

This study used the Cronbach's alpha also known as alpha co-efficient to determine the reliability or internal consistence of the questionnaire and its constructs. The overall reliability of the questionnaire with 32 items as demonstrated in Table 1 was found to be 0.960, which reliability was considered good since it was above the recommended threshold of 0.7, and also comparing the number of items in the questionnaire (Heale & Twycross, 2015).

Table 1
Overall Reliability Statistics of the Measuring Instrument

Reliability statistics		
Cronbach's alpha	Cronbach's alpha based on standardized items	Number of items
0.960	0.960	32

Results

The set of hypotheses were evaluated using regression analysis, with the findings being reported. The statistical analysis of the data were performed using SPSS 25.0. According to Cohen et al. (2018), a significance level of 0.05 is regarded as acceptable. By providing a relationship between the variables that could be used to predict the values of the independent variables. The findings demonstrated in Table 1 show that all the hypothesized relationships were accepted, with the exception of environmental aspects in order to develop the final research model. The population of the study based on the district hospital level was 150 respondents. Age, level of education, work experience, job position and cloud awareness were the different demographic and situational variables that were identified as being relevant for this study. Participant's demographics are shown in Table 2, which is broken down into the relevant categories..

Table 2
Frequencies of Participants' Demographics

Factors	Items	Frequency		
		People (n)	Percentage (%)	Cumulative percentage (%)
Age	21-30 years	27	32.5	32.5
	31-40 years	36	43.4	75.9
	41-50 years	20	24.1	100.0
	Total	83	100.0	100.0
Level of education	Grade 12 and below	6	7.2	7.2
	Diploma	24	28.9	36.1
	Advanced diploma	7	8.4	44.5
	Degree	27	32.5	77.0
	Post Graduate	19	22.9	100.0
	Total	83	100.0	100.0
Experience	0-5 years	38	45.8	45.8
	6-10 years	26	31.3	77.1
	11-15 years	7	8.4	85.5
	16-20 years	3	3.6	89.1
	21-25 years	3	3.6	92.7
	26 years and above	6	7.2	100.0
	Total	83	100.0	100.0
Job position	Administrator	13	15.7	15.7
	Cleaner	5	6.0	21.7
	Doctor	8	9.6	31.3
	Driver	1	1.2	32.5
	Filing Assistant	1	1.2	33.7
	Lab Assistant	1	1.2	34.9
	Matron	2	2.4	37.3
	Nurse	41	49.4	86.7
	Porter	2	2.4	89.2
	Surgeon	9	10.8	100.0
	Total	83	100.0	100.0
Cloud computing	No	16	19.3	19.3
	Yes	67	80.7	100.0
	Total	83	100.0	100.0

As demonstrated in Table 2, over 67.5% (n=56) of the respondents were above the age of 30 years. These respondents had a good level of education with only 28.9% (n=24) having an education level of a diploma. The implication of these findings is that such respondents could make a good decision about the asked question that improved the validity of the results obtained for this study. The respondents' level of education is presented graphically (Figure 1).

The age as a demographic variable has been found by other researchers (Kalema, 2013; Venkatesh et al., 2012) to be a good predicting factor in the studies of technological innovation implementation. This implies that in terms of migrating HMS in the cloud-based environment, mature individuals are more responsible in observing controls and measures, security rules as well as guidelines. Consequently, this also implies that the questionnaire was answered by responsible people within the healthcare facilities.

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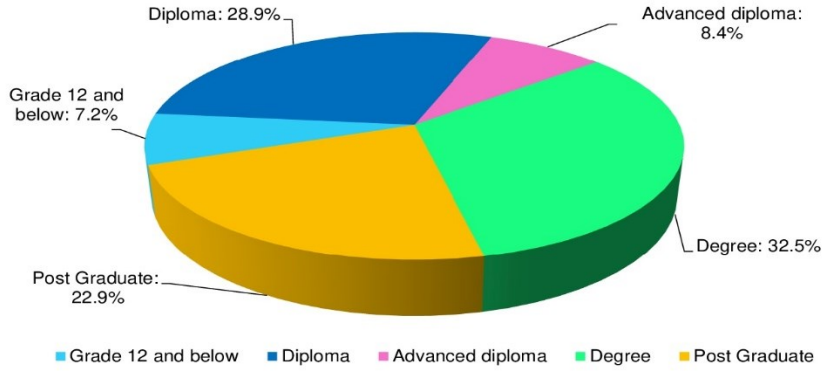
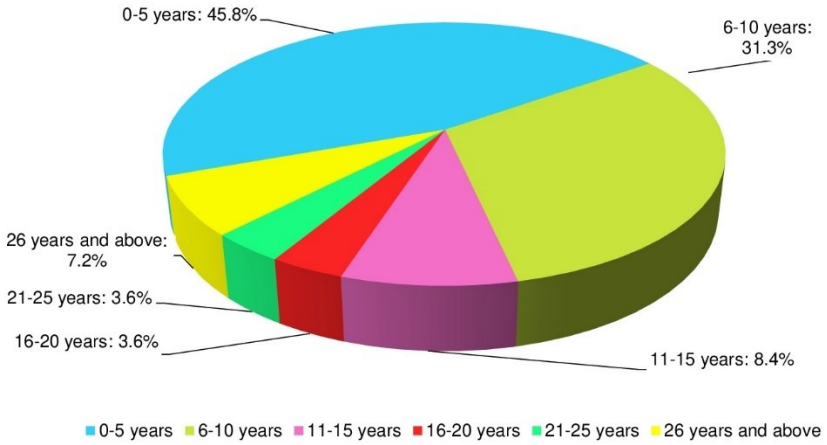
Figure 1
Respondents' Level of Education



It is also demonstrated in Table 2 that 15.7% (n=13) of contributions to this study were from hospital administrators, 7.0% (n=5) were from cleaners, doctors contributed 9.6% (n=8), drivers, filling assistants, and lab assistants each contributed 1.2% (n=1). A contribution of 2.4% (n=2) was from matrons, nurses contributed 49.4% (n=41), porters 2.4% (n=2) and surgeons contributed 10.8% (n=9). Relevance of the job title as well as seniority plays an important role in maintaining data integrity that leads to better decision-making. The role of an individual's position within an organization has been identified in various technological innovation based studies as being critical and having high interacting effects on the overall prediction of models explaining technology acceptance and use (Kalema, 2013; Rahim et al., 2022; Venkatesh et al., 2012).

Results demonstrated in Table 2 indicate that 45.8% (n=38) of the participants have at least 5 years of work experience, 31.3% (n=26) have between 6 and 10 years, 8.4% (n=7) have between 11 and 15 years, 3.6% (n=3) have between 16 and 20 years, 3.6% (n=3) have between 21 and 25 years, and 7.2% (n=6) have more than 26 years. Experience places an individual in a position of responsibility, source of knowledge and wisdom as one with a good experience within an organization is considered a master of processes and operations. Previous researchers (Tripathi, 2018; Williams et al., 2016) note that individuals with good experience are considered as the knowledge base of the organization. This implies that since a good number of respondents of this study (54.2% or n=45) had experience of 6 years and above, it signifies that data for this study was collected from the "knowledge base" of the hospitals' financial institutions. The work experience of the respondents is presented graphically (Figure 2).

Figure 2
Overall Working Experience



Respondents were also asked to show the awareness of the cloud environment. Results indicated that 80.7% (n=67) of the participants had knowledge or were aware of the cloud whereas 19.3% (n=16) indicated that they were not aware of the cloud computing concept. When users are aware of a technological innovation, its implementation becomes less complicated as little sensitization will be needed during the implementation process.

Regression Analysis

Further to descriptive analysis, a regression analysis was conducted to determine the prediction of the overall model as well as how much each independent variable contribute to the overall prediction of the model. The model was found to have a good prediction power of 60.9% (R^2=0.609). The prediction contribution for each independent variable is illustrated in the results of regression analysis (Table 3).

Table 3

*Regression Coefficients**

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.	Collinearity statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	0.359	0.062	-	5.790	0.000	-	-
TechChar	0.429	0.218	0.139	1.967	0.042	0.257	3.889
CloudComRead	0.407	0.148	0.256	2.756	0.023	0.370	2.701
OrgAsp	0.759	0.214	0.284	3.549	0.016	0.234	4.272
EnvtAsp	-0.136	0.205	-0.123	-.664	0.509	0.228	4.387
IndChar	0.595	0.195	0.182	3.051	0.017	0.263	3.803
RiskAnCtrl	0.487	0.182	0.413	2.681	0.009	0.331	3.018
SocAsp	-0.701	0.193	-0.600	-3.632	0.001	0.289	3.458

Note. *Dependent variable – cloud-based Hospital Management System.

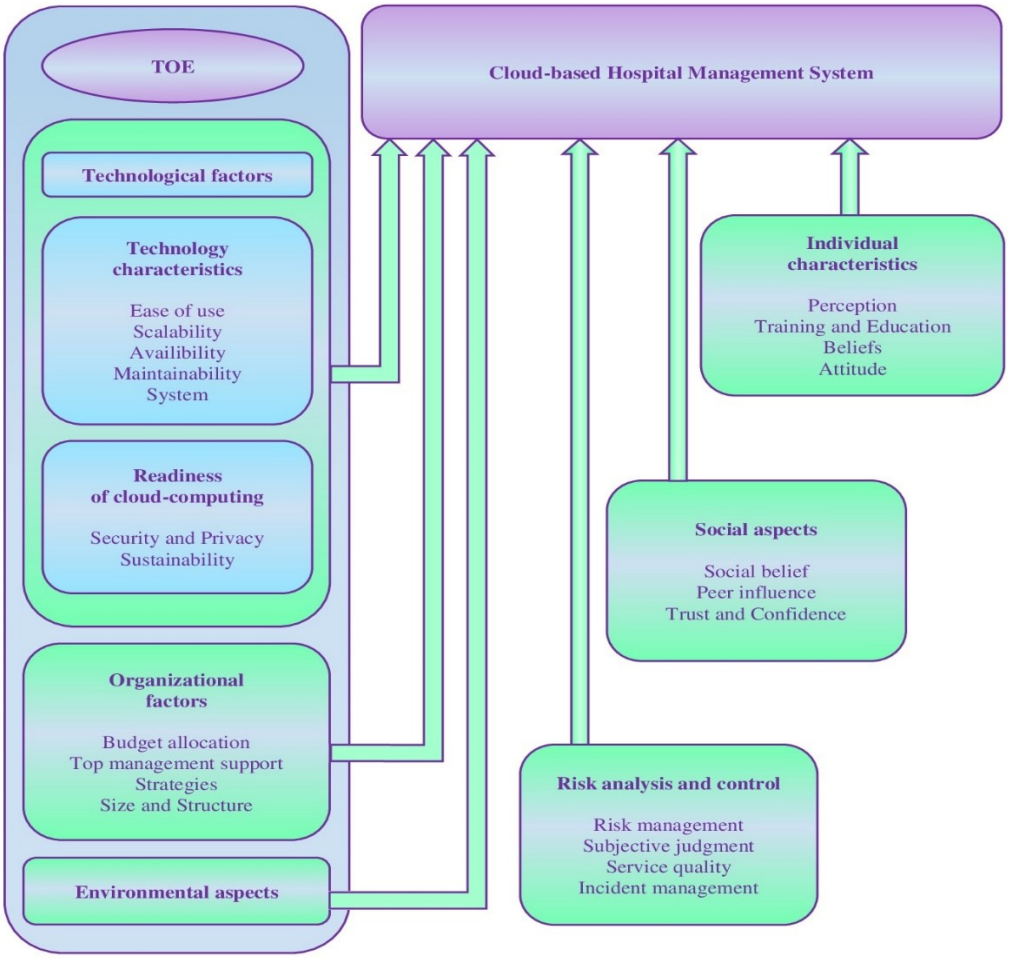
Results demonstrated in Table 3 indicate that with the exception of environmental aspects, the rest of the constructs showed a significant contribution to the successful implementation of a cloud-based HMS. Social aspects had the highest contribution with the prediction power of 60.0% (β=0.600) at p=0.001; followed by risk analysis and control with a prediction power of 41.3% (β=0.413) at p=0.009. On the other hand, environmental aspects' contribution of 12.3% at p=0.509 was relatively high, it was found not to be significant.

Table 3 also measured the existence of multi collinearity by using the Variance Inflation Factor (VIF). The rule of thumb indicates that for multicollinearity collinearity to exist, the value of VIF>10. However, as indicated in Table 3, all the VIF values were less than 5, which indicated that multicollinearity does not exist.

Based on the findings, the conceptualized model for cloud-based Hospital Management Systems for the South African public health sector was derived as demonstrated in Figure 3.

Figure 3

Model for Cloud-Based Hospital Management System



**Note.* TOE – Technology-Organization-Environment framework.

Discussion

Based on the results of the study, the implications of the significance of the variables demonstrated in Figure 3 should be explained.

The Technology-Organization-Environment model developed by De Pietro et al. (1990) underpinned the development of the cloud-based Hospital Management Systems.

Technological factors

The implication of this finding is that on average there have been challenges of inadequate health institutions and shortage of healthcare human resource in many developing countries, especially those in Sub-Saharan Africa (Kalema & Busobozi, 2020). Hence, technology and its innovations are seen as one way to bridge the gap of resource constraint by providing remote access capabilities to healthcare resources. The significance of this variable confirms the fact that citizens appreciate the value and contribution of technology towards healthcare provision and such good and available technology will boost the migration of HMS to the cloud environment. On the other hand, technological aspects are perceived to be a major part of cloud technology and a basis for the cloud to change the computing process from using the HMS as stand-alone systems to a networked system that solves the challenges of accessibility and governance, especially in resource-constrained organizations like hospitals. The finding of this study is in agreement with those of previous researchers (Idoga et al., 2019; Sadoughi et al., 2020) who also stated that regardless of how technology is looked at as either top-down or bottom-up; its role for cloud migration is enormous.

Organizational factors

The significance of this variable implies that organizational aspects that entail factors like top management support, budgets and finances, employees' empowerment for knowledge creation through trainings, policies and standards, organizational size and structure, measures for collaboration and knowledge sharing, as well as enhanced business processes play an essential role in the migration of services and applications to the cloud. The findings of this study concur with those of many previous others on the migration to the cloud that have found organization aspects to have a stronger significant influence (Alipour et al., 2021; Idoga et al., 2018; Sadoughi et al., 2020).

Environmental aspects

Environment aspects have been found in various healthcare research of developing countries to be significant, yet they were found not to be significant in this study (Kalema & Busobozi, 2020; Maphumulo & Bhengu, 2019). The implication of this finding is that when services are migrated to the cloud the issue of environment is overshadowed by the organizational aspects. For instance, services will be migrated to the cloud that might reside in a different country or continent and such migration requires more organizational support than the environment characteristics. With good support from the organizational top management in terms of budgets, training of users, employing the right staff, signing good service level agreements with vendors to assist with configuration management, provisioning required tools, assisting with log collections, patching systems and ticketing systems, cloud-based activities may have little hindrance as compared to the on-premises IT facilities.

Individual characteristics

Individual characteristics have been found in much previous research of technological innovation adoption, implementation and use to be significant (Adler-Milstein et al., 2015; Kalema & Busobozi, 2020). The implication of these findings is that individual characteristics like attitude and beliefs, perceptions, training, and education are crucial for cloud migration because when services are migrated the success of the administrative tasks will depend on the capabilities of the individuals to manage both the migration processes and the operation. Another factor to consider is that migration of a Hospital Information System (HIS) to the cloud comes with several advantages for both healthcare providers and patients in terms of quality service delivery and cost-efficient solutions to the patients, as well as having seamless collaborations among healthcare facilities. These findings concur with those of other researchers (Idoga et al., 2019; Singh et al., 2022) who also noted that cloud-based hospital systems support collaborations that bring efficient data exchange with fast feedback for the patients through information sharing, but such could only be achieved if individuals using the systems have the capabilities and positive perceptions towards the system.

Social aspects

The significance of this variable implies that cloud migration has a high dependence on information sharing due to its potential to provide remote access to data. The social interaction could be either internal or external and as such supports information sharing and unrestricted flow of information in the cloud-based health system, which leads to effectiveness. Internal social aspects include influence of others to accept, and believe and trust in the system; while the external is related to external collaboration when the system is migrated and support during the use of the system. The findings of this study support those of previous researchers such as (Venkatesh et al., 2012; Walker & Walker, 2022) who noted that social aspects play an essential role in voluntary technological innovation implementation, adoption, and use.

Risk analysis and control

The significance of this variable confirms the fact that risk awareness starts with identifying and reporting near accidents, incidents, complaints, or other undesirable situations that could be the order of the day in the cloud environment. This implies that risk management in the cloud should embrace a flexible software platform that can record and detail the data and its operations, direct follow up of workflow automation tools, carry out analysis of trends of root causes of risks and associated challenges, manage dashboards to monitor information, as well as monitor improvement actions. The findings of this study concur with those of other researchers (Alipour et al., 2021; Maphumulo & Bhengu, 2019; Rahman et al., 2017; Singh et al., 2022) who also observed that

managing risks associated with HIS is paramount in assuring patients' safety regardless of hospital size and structure. Hence, risk management and control is a significant factor for migrating HIS to the cloud and healthcare systems should be mindful of the techniques that they use to migrate their services.

Cloud-based services migration has many implications, such as budgets and costs to technical aspects including maintenance and delivery. This implies that to get a vivid understanding and generalization of findings for the migration of HIS to the cloud environment, this study needed to involve as many stakeholders as possible who interact with the system. However, because this study collected online data, some stakeholders could not participate in the study for one reason or the other. More so, this study also needed to triangulate the methods during data collection whereby some data would have been collected qualitatively from policy makers, like top hospital administrators, through interviews. This study, therefore, recommends that future research should increase the scope of data collection by increasing the number of participating hospitals in the study and try to triangulate the methods by using a combination of quantitative and qualitative data collection methods, such as interviewing policy and strategic decision makers.

For conclusiveness of a cloud-based HIS, one needs to do a follow up of what happens after migration. This could also be in the form of observing the adherence to policies and standards as well as assessment of the reduction in the total cost of ownership of the system after migration. Therefore, since a cross-sectional data collection approach was used, this study recommends that a longitudinal research data collection should be used by future researchers in order to be in an actual position to report what will happen after some time. A longitudinal survey will also assist in determining whether medical personnel and healthcare workers are effectively using the system.

Several researchers (Kalema, 2013; Rahim et al., 2022; Tripathi, 2018) note that users of technology may have their perceptions change with time. This implies that analysis of users' demographics and situational variables should go beyond descriptive and analyse the moderating and interacting effects of these variables in order to make a better prediction of what happens after some time interval. Much as this study appreciates this observation, respondent's demographics and situational variables were only analysed using descriptive analysis to show the frequencies. This may cause a limitation in predicting future occurrences in the usage of the cloud services. This study recommends that future research should make effort to analyse the interacting effects of the moderating factors.

Conclusions

Migrating services and applications to the cloud is a big step. However, it is the first step as migration is one thing and administering the use of the migrated services is another. A successful cloud-based HIS requires the healthcare system to remain active and vigilant, hence the need to train all stakeholders to achieve advanced skills that will enable them to use these migrated services. As emphasized by Sadoughi et al. (2020), keeping and maintaining cloud security is a pain-staking task that needs any organization to remain abreast with technological developments, and to be many steps ahead of its adversaries. Cloud migration complacency may be limiting in informing a successful cloud strategy; hence, organizations need to have constant evaluation of what their IT support team can do better and how such can be achieved.

This study revealed that organizational, technological, individual, and social aspects as well as risk control and analysis are important determinants in shaping the perspective of cloud-based HIS users. However, the cloud-based system characteristics such as ease-of-use, relative advantage, scalability, security, and trust are major antecedents in accepting a cloud-based HIS. This implies that an organization needs to simplify the understanding and use of the cloud by users by enhancing their capabilities through training as well as involving them in the decision-making process around the migration to the cloud.

As observed by recent researchers (Abbas et al., 2020; Kalema, 2022; Singh et al., 2022) in the current era of the Fourth Industrial Revolution (4IR), the greatest opportunities as well as the greatest threats are the new trends in computing. This technology "Big Bang" has and is continuously changing the landscape of every organization, including those in the healthcare sector. Migrating services to the cloud is increasingly becoming the order of the day for those organizations seeking agility. Since such has made the cloud to move faster, the earlier organizations gain diversified expertise in using and administering services in this environment the better is their future survival. As a result, the model designed for this study could be a beneficial guide to empirical research on cloud-based systems, not only for the healthcare sector but also for other sectors. The findings of this study are intended to help healthcare decision-makers by increasing their awareness of the cloud-based systems, and to keep in mind the impact of the identified factors on decision-making at all levels within healthcare.

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Ethical Approval

The study obtained ethical clearance from the institution Ethics Committee (Ref. No. FCRE/ICT/2021/06/002(1).

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