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SECURE MODEL FOR ERP-CLOUD INTEGRATION FOR SUSTAINABLE DIGITAL TRANSFORMATION IN KENYAN UNIVERSITIES

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Abstract: Cloud-based Enterprise Resource Planning (ERP) systems promise simplified operations and increased efficiency. However, their acceptance in Kenyan universities is still in its initial stage of implementation due to financial limitations, legacy system incompatibilities, and a lack of specialized expertise. Additionally, integrating ERPs with cloud services presents complex security challenges. The study highlighted widespread concerns regarding data breaches, unauthorized access, and compliance with Kenyan data protection laws, as well as the Data Act of 2019. The study found a substantial security-usability trade-off, where the need to maintain strong data protection conflicts with the demand for increased functionality through cloud integration. This study proposed the Adaptive Trust Model in response to these difficulties and with direct input from the empirical results. This paradigm offers Kenyan universities a safe and contextually appropriate framework for combining cloud services and ERPs. The development of this model is crucial, as the findings indicated the inadequacy of generic security solutions in addressing the unique infrastructural and regulatory landscape of Kenyan universities. A comprehensive literature review was conducted to analyze past contributions and contextualize the study's findings. Cluster sampling was employed to select a representative sample of universities, and data analysis was performed using R software, facilitating both quantitative and qualitative insights.

Keywords: ERP, cloud computing, secure integration, Kenyan universities, data protection, Adaptive Trust Model, digital transformation.

I. INTRODUCTION

ERP (Enterprise Resource Planning) is a management information system that was developed using information technology and a systematic Management concept [1]. It is a comprehensive computer program for managing both internal and external resources such as tangible assets, financial resources, materials, and human resources. ERP software allows us to optimize and share resources by integrating the material, production, supply, marketing, economic, and related logistics, information flow, manage flow, cash flow, value flow, and others [2]. ERP is suitable for all three levels of Management, i.e., strategic, tactical, and operational levels. Nowadays, ERP can be applied to any type of organization operating in any field. [3].However, cloud computing represents a new paradigm in computing. [4]. It is an online service that allows clients to receive hardware and software services based on their needs and is paid for as an operational expense without incurring significant costs.

Cloud computing is a collection of services that offer data storage on a third-party server and infrastructure resources via the Internet. [5]. Platform as a Service (PaaS), Software as a Service (SaaS), and Infrastructure as a Service (IaaS) are its three dimensions. Infrastructure as a Service (IaaS) delivers computer infrastructure, typically a platform virtualization environment where a service customer buys their needed infrastructure, owns and purchases software, and virtual power to execute as required. [6]. In a virtual environment, this service is a virtual server that is operational. [7]. Operating systems, middleware, application software, or an environment that encapsulates the services can all be integrated using Platform as a Service (PaaS). It uses web browsers or client applications, which are made available by cloud providers via the Internet and are built on virtual machines. By delivering software as a service (SaaS) via the Internet, customers can avoid installing and running the application on their PCs and simplify maintenance and support.

[8].The multi-tenancy idea and virtualization, two significant technological advancements, are the roots of the services provided by cloud computing [9]. The shared use of a software program (and related code) by multiple parties, each of whom uses a separate data space, is known as multi-tenancy. By enabling virtual machines to operate alongside one

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another on shared hardware, virtualization is the physical sharing of hardware capacity (machines) [10]. One of the more sophisticated concepts in information and communications technology (ICT) is cloud-based ERP [11]. It is a combination of business processes and technology. [12]. Kiadehi and Mohammadi claim that an ERP is composed of a variety of activities that increase an organization's performance and that all of an organization's data and procedures are gathered in a single system. [13]. Three ERP deployment strategies—on-premise, hosting, and on-demand—have been embraced by enterprises recently [14]. The different tools available under cloud computing provide the lowest-cost working environment and are suitable for developing economies [15]. There is massive research going on to integrate ERPs with the cloud [16]. In the current environment, a large of businesses are using cloud-based ERP systems [17]. There are various reasons for choosing cloud-based ERPs over traditional standalone ERPs [18]. The hardware and software components of cloud-based ERP systems support the main business operations [19].

[19]. Cloud services have recently been the ultimate solution for companies seeking to achieve both efficiency and cost-cutting [20]; hence, building high-quality cloud applications has become an immediately required research problem in cloud computing technology [21]. Many organizations are yet to benefit from the advantages that come with ERPs integrated with the cloud. This research aims to build a secure model that universities in Kenya will use to integrate their ERPs with cloud services.

The contributions of this study are threefold:

1. An extensive empirical investigation into ERP-cloud integration in Kenyan higher education.
2. The design of a novel, context-sensitive security model —Adaptive Trust Model for ERP-cloud integration.
3. Practical policy and technical recommendations for sustainable digital transformation in resource-constrained academic environments.

The remainder of this paper is organized as follows. Section 2 provides a review of related literature. Section 3 presents the methodology used in the research. Section 4 discusses findings from the data collection. Section 5 proposes the Adaptive Trust Model. Section 6 provides a conclusion. Section 7 provides a recommendations and suggests directions for future research.

II. RELATED WORK

CONVENTIONAL ERP

Before the standard ERP concept came up, it had been evolving for several generations. ERPs originated from MRP (Material Requirements Planning), which was born in the late 1960s and developed in the 1970s [22]. The goal of MRP is to guarantee the enterprise production operations, at the same time controlling the inventory. The move beyond MRP was driven by a need for stronger Integration between the functional enterprise silos that dominated firms throughout this period. [23].

Production management is only one aspect of enterprise management, and the cash flow that is closely related to operations was often administered separately by the financial functions, which resulted in data duplication and even data inconsistencies. In 1990, an integrated enterprise solution was proposed. [24], and the concept is what is called ERP now [22] [25].

The traditional or conventional ERP is of two types: on-premises ERP and hosted ERP (22). In the on-premises system, the software is licensed-based. [26]. It is often treated as a capital expense. In the case of hosted ERPs, the licensed applications are hosted by a third party. This is deployed as a separate instance of hardware dedicated to the organization or a separate virtual instance dedicated to an organization. [27]. Sometimes, it is deployed using a private cloud, where the example of ERP is hosted by a third party and delivered to the end-user on a subscription basis. This may or may not be deployed via the Internet.

The advantages of on-premise ERP systems are high customizability and they offer greater control over data. Longer implementation time and high cost of owning the licensed software and associated hardware and IT tools are the downsides of on-premises are the disadvantages of the on-premises ERPs [28]. Therefore, now with the change of trend, organizations find that cloud ERP systems are more comfortable and suitable for the business.

ERP has been evolving for generations, starting from a material requirement planning application to an enterprise resource planning software that includes several modules that involve all the business key functionalities and make them easier [29].

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On-premises software is the traditional method of implementation, where you buy the software license and install the software on your in-house hardware. Your internal IT staff maintains the software and handles upgrades. Arnesen and Spencer are quoted as saying that in some cases, you can outsource support of the software to a third-party IT service provider even though the software is installed on your hardware. [30].

Cloud computing and cloud ERP

Cloud computing has been a promising trend where applications, hardware, and software are delivered as a service via the Internet. The capability to provide a variety of IT services on demand is the fundamental characteristic of cloud computing. [31]. "The cloud computing services are offered in 3 forms: Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS).

IaaS offers infrastructure on demand in the form of virtual hardware, storage, and networking. Platform-as-a-service solutions deliver scalable and elastic runtime environments on demand and host the execution of applications, which are backed by a core middleware platform that is responsible for creating the abstract environment where applications are deployed and executed. [31]. Software-as-a-service solutions provide applications and services on demand. Windows Azure, Facebook, and Salesforce sales are some examples of SaaS. These applications are shared across multiple users over the internet, whose interaction is isolated from the other users.

There are many ERP solutions offered in the market as cloud ERP solutions. Cloud ERP solutions are provided via the software-as-a-service model of cloud computing. [32]. They are accessible via an internet browser without installing or configuring the system on the user's side. The advantages of cloud ERP are scalability, reliability, availability, mobility, accessibility, usability, and low cost compared to the implementation of on-premises systems. The downside is that they are less customizable and may have data security and integrity concerns. [33].

There is plenty of research done analyzing the cloud concept and the types, though it is comparatively new. This shows the dominance of cloud technology. Buyya et al. state that there are three major models for deploying and accessing cloud computing environments. [34]. They are public clouds, the most common deployment models in which necessary IT infrastructure is established by a third-party service provider that makes it available to any consumer on a subscription basis; in private/enterprise clouds, the cloud infrastructure is operated solely for a business or organization, and serves customers within the business fire-wall and hybrid cloud, a composition of private Cloud and public Cloud.

Cloud ERP solutions are delivered via the software-as-a-service model. Scavo et al. state that it is important to note that some ERP solutions that are marketed as 'cloud-based' are hosted ERP solutions. [35]. These systems are typically accessed by a standard browser over an Internet connection, allowing access that has little dependency on client configuration. Examples in this relatively new category include sales force software, SAP Business by Design, which was coded separately from its existing on-premise system.

The factors affecting the adoption of ERP as SaaS are cost, security, availability, usability, implementation, ubiquity, flexibility, comparability, analytics, and best practices, according to Björn et al. [36]. As stated in the literature on exploring factors affecting the service quality of ERP on the cloud [37], the advantages of cloud ERP are: less risk, no upfront cost, controlled, secure, ubiquitous access, streamlined operations, and automatic and cost-free scalability, which make it highly preferable.

Integration and factors affecting the Integration of a conventional ERP system to the cloud

There is enough research on conventional ERP adoption and conversion to cloud-based ERP. [38]. However, very few are available from the integration perspective. Shi Jai, in his study on "Integrating conventional ERP system with cloud services: from the perspective of cloud service type" [39], states that Integration has become a trend as it brings new processing capabilities without introducing significant changes to existing systems. Also, he states that this integration-related study mainly focuses on software as a Service.

In his study, the respective implications of integrating ERP with three types of cloud services, SaaS, PaaS, and IaaS, are analyzed. He also states that Integration at the SaaS level is for achieving immediate business value and productivity enhancement. At the PaaS level, the objective of Integration is to enhance software development life cycle management. The primary integrating intent at the IaaS level is to enable the scalability and reliability of hardware resources without changing the existing IT infrastructure. [39].

Björn Johansson has taken ten factors that affect the Integration of conventional ERP systems to the cloud into consideration. [40]. They are costs, security, availability, usability, implementation, ubiquity, flexibility, compatibility, analytics, and best practices in the ranking order.

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However, the research by Björn Johansson does not consider Integration as an essential part. It concludes that these factors play the least role when it comes to the Integration of conventional ERP systems with the cloud, as it needs more variable functional and non-functional requirements. [40].

The research by Wei Sun states that "though SaaS is delivered over the internet and charged on a per-user basis, it is a software application in essence. [41]. SaaS contains business data and logic, which are usually required to integrate with other applications deployed by a SaaS subscriber. This makes Integration one of the standard requirements in most SaaS adoption. Here, the integration requirements are considered, and the factors influencing the Integration are analyzed only based on the SaaS model of cloud computing.

When considering the factors affecting Integration, though many kinds of literature do not specifically discuss on-premises and cloud ERP integration, those found can be generalized to this scenario depending on the relevance. Literature on Supply chain integration through community cloud: Effects on operational performance states that the factors affecting Integration are physical and informational flow integration, flexibility, and deliveries [42]. Shi Jia, in his research, discusses that the lack of customization opportunities is one of the downfalls of conventional ERP systems(ref). A case study-based research on Application Integration: Enterprise Resource Planning (ERP) systems in the hospitality industry states that the factors affecting Integration are flexibility and adaptability [43]. In the literature on BI and ERP Integration, it is noted that technical innovation, reliability and availability, scale efficiency, and system flexibility are the main concerns of Integration. [44].

Pei-Fang Hsu states that ERP and E-business integration are affected by factors such as business process coordination, cost efficiency, differentiation, and intangible benefits. [45]. According to Kleeberg, market fluctuations, organizational issues, and economic questions affect Integration in addition to technical challenges. [46].

Research by Rajiv Malhotra states that the project team structure, implementation strategy, database conversion strategy, risk, and change management strategies have an impact on Integration. [47]. According to Prashantha, there are various approaches that a company can take to accomplish Integration between PLM and ERP. Each approach will provide differing levels and complexity of Integration, functionality, scope, and cost of implementation and support. Companies need to assess the issues described previously and select the best approach based on their specific needs, plans, current infrastructure, and estimated costs. [48].

The new generation of integration solutions features single, robust integration platforms designed to deliver everything needed for cloud and conventional ERP integration. The ideal integration platform provides complete deployment flexibility, integration capabilities, connectivity, and reusability. [49]. Estefania, in her research, categorizes Integration into technical Integration, business integration, and socio-organizational Integration. Technical innovation, reliability and availability, scale efficiency, and system flexibility are the main concerns of Integration. [50].

Based on the literature, most of the research on Integration was done after 2007, and some specifically discussed module-to-module integration and Integration on the basis of cloud architecture. Not many articles discuss the generalized Integration of conventional ERP systems to the cloud. Though not all ERP integrations are similar, most can be generalized to our case. Factors such as system flexibility, compatibility, informational Integration, business flexibility, innovations, cost, user satisfaction, interaction among vendors, and change management are discussed repeatedly in literature, which can be categorized into three types of Integration as mentioned in earlier technical Integration, Business Integration, and Socio- socio-organizational integration.

III. METHODOLOGY

This study adopted a mixed-methods research design, combining qualitative methods where a questionnaire and quantitative surveys. The study was conducted in 20 universities in Kenya, both public and private, from 36 universities. Sampling was done to determine the number of universities to be visited. ICT managers and other resourceful persons from those universities were requested to provide information that formed the basis of the data that was used in the study. The analysis of data gave in-depth information on how universities in Kenya are using ERPs and, by extension, the level at which Integration with cloud services is. A structured questionnaire was designed to collect quantitative data on: adoption status, Current integration with cloud services, Perceptions of benefits and risks, Security practices, and compliance efforts. The survey included both closed-ended and Likert-scale questions. It was pre-tested on a small sample and refined for clarity and reliability.

In-depth interviews were conducted with ICT directors and senior administrators in 15 selected universities. The interviews focused on: Institutional experiences with ERP-cloud integration, Specific security and regulatory concerns,

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Perceived barriers to adoption, and Expectations for a secure integration model. All interviews were recorded with consent and later transcribed for thematic analysis. Quantitative data from surveys were analyzed using R statistical software.

Descriptive statistics were used to summarize ERP implementation levels, cloud service utilization, and security concern frequencies. Cross-tabulations and chi-square tests were applied to explore differences between public and private institutions.

ERP-Cloud Integration Status

While cloud adoption is growing, only 20% of universities reported full ERP-cloud integration. The majority (80%) use cloud services for :Data storage (IaaS), Web hosting and development (PaaS), and Productivity tools (SaaS). This aligns with Shi Jia's findings that IaaS dominates in early-stage ERP-cloud integrations [42]. Respondents cited key benefits of cloud integration as Scalability (85%), Cost reduction (78%), and Improved service delivery (80%). Private institutions reported a higher emphasis on usability, while public institutions valued scalability, reflecting their larger data volumes and more complex operations [44], [45].

Interviews revealed several security concerns: Data breaches and unauthorized access [5], [17], [24], Compliance with Kenya's Data Protection Act (2019) [16], Loss of control over sensitive data hosted on foreign servers [13], [20]. Respondents stressed the security-usability trade-off, where stricter controls reduce accessibility and efficiency, consistent with Kshetri's framework on cloud risks in developing economies [14].ICT managers emphasized that regulatory frameworks lag behind cloud technology evolution, creating ambiguity in compliance obligations [15], [24]. This was echoed in Ojo et al.'s work on digital government regulation in developing countries [30]. A significant observation was that ICT departments often lacked autonomy or budgetary control to drive secure cloud initiatives. This reflects the principal-agent dilemma where decision-makers (principals) are disconnected from implementers (agents), leading to misaligned priorities [56].

IV. FINDINGS

The survey revealed that ERP adoption in Kenyan universities is uneven: Public Universities: 20% had full ERP implementation, 50% had partial implementation, and 30% had no formal ERP system. Private Universities: 35% had full implementation, 45% partial, and 20% had none. Universities with full ERP systems often use vendor solutions like SAP or Oracle, while smaller institutions prefer open-source platforms like Odoo. These trends are consistent with findings by Elmrabat et al. [34] and Foaysal et al. [35], which highlight the influence of institutional size and financial capacity on ERP adoption.The seeming benefits of cloud integration which include scalability and cost-effectiveness, were widely recognized. Nevertheless, security concerns, mainly regarding data sovereignty and compliance with local regulations, posed significant barriers to seamless Integration.

Barriers to ERP Implementation include: Budget constraints [12], [20], Legacy infrastructure incompatibility [43], [48], Lack of skilled personnel [24], [29], Resistance to change, and poor project management [50]. These findings confirm earlier literature suggesting that ERP success requires organizational readiness, change management, and leadership support [28], [46].In response to financial limitations, some universities adopted phased implementation strategies, prioritizing finance and student administration modules first. A few reported developing in-house ERP modules to reduce costs—evidence of resource-constrained innovation [49].

V. DEVELOPMENT OF THE ADAPTIVE TRUST MODEL

Key Components of the Adaptive Trust Model

The Adaptive Trust Model is a dynamic framework that emphasizes continuous monitoring and adaptation to evolving security threats. It comprises the following key components:

- **Risk Assessment:** A systematic process for identifying and evaluating potential security risks associated with ERP-cloud integration. This includes assessing vulnerabilities in cloud infrastructure, data transmission, and access control mechanisms. This component emphasizes the need for regular risk assessments, as threats and vulnerabilities are constantly evolving.
- **Data Encryption:** Implementation of robust encryption techniques to protect sensitive data both in transit and at rest. This includes using industry-standard encryption algorithms and key management practices.
- **Access Control:** Establishment of granular access control policies to ensure that only authorized users can access specific data and functionalities. This includes implementing role-based access control (RBAC) and multi-factor authentication (MFA).

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- **Continuous Monitoring:** Implementation of real-time monitoring systems to detect and respond to security incidents. This includes logging and analyzing network traffic, system logs, and user activity. This component allows for proactive identification and mitigation of security threats.
- **Distributed Trust:** Recognizing that security is a shared responsibility among the university, cloud service providers, and users. This involves establishing clear roles and responsibilities and fostering a culture of security awareness. This component highlights the importance of collaboration and communication in maintaining security.

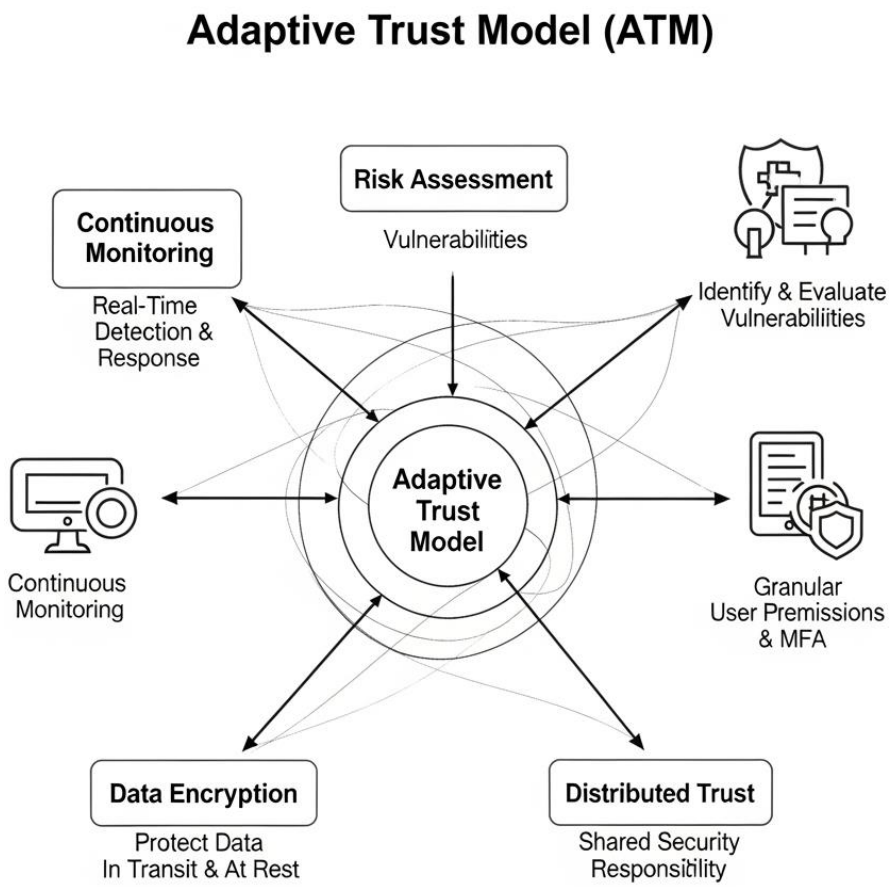

Diagram illustrating the key components of the Adaptive Trust Model and their relationships

VI. CONCLUSION

The successful Integration of ERP systems with cloud services is critical for the sustainable digital transformation of Kenyan universities. Nevertheless, this Integration must be approached with a keen awareness of the inherent security challenges and a commitment to developing context-specific solutions. The Adaptive Trust Model offers a pathaway for realizing this, highlighting the need for continuous monitoring, strong security measures, and collaborative partnerships. As Kenyan universities increasingly rely on digital technologies to support their academic and administrative functions, the security of their data and systems becomes paramount. Universities can leverage the benefits of cloud computing while mitigating the associated risks by adopting a universal and adaptive approach, thereby paving the way for a more efficient, secure, and technologically advanced higher education sector in Kenya.

VII. RECOMMENDATIONS AND FURTHER DIRECTIONS

Kenyan universities must create comprehensive strategic plans that address their unique resource constraints and security needs to effectively implement ERP-cloud integration. By providing continual training for ICT staff and ensuring they are well-versed in the latest cloud technologies and security protocols, Universities should invest in developing internal technical capacity. Furthermore, the implementation of enhanced security measures must be a priority, with a focus on preserving data sovereignty. Adopting the adaptive trust model can further improve system resilience and security.

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Establishing precise regulatory frameworks and guidelines that control ERP-cloud integration within the higher education sector is a critical role for Policymakers. These rules ought to improve data security, standardize practices, and provide clarity on compliance. Additionally, the shift to cloud-based systems can be facilitated by providing financial incentives and technical support to universities. Collaboration among universities, cloud service providers, and regulatory authorities can promote knowledge sharing and streamline integration processes.

Cloud service providers ought to modify their products to meet the specific operational and academic needs of Kenyan universities. Their solutions must include advanced security features and be fully compliant with Kenyan data protection laws. In addition to delivering secure and scalable platforms, providers should also provide comprehensive training and ongoing support to ensure that university staff are equipped with the skills necessary to manage and maintain cloud environments effectively. The path to a safe and long-lasting digital transformation in the higher education industry will be paved by this cooperative and well-supported strategy.

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International Journal of Advanced Research in Computer and Communication Engineering

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