Vol. 08, Issue 09, September: 2020
ISSN(P) 2347-5404 ISSN(O)2320 771X

Security and Compliance Challenges in Deploying SAP on AWS

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ABSTRACT

SAP system deployment on cloud infrastructure, especially on Amazon Web Services (AWS), has gained strong momentum due to its flexibility, cost savings, and ease of operations. However, SAP deployment with AWS accrues numerous security and compliance challenges that could offset the advantages of cloud computing. This study examines the security and compliance issues of organizations in deploying SAP on AWS, with emphasis on key findings of studies from 2015 to 2020. One of the key concerns isolated is data privacy and protection assurance, particularly in the aftermath of strict data residency and sovereignty regulations. In spite of the availability of a variety of security tools from AWS, there is a lacuna in SAP configuration compliance against industry-specific regulations like HIPAA, PCI-DSS, and GDPR. In addition, studies indicate the complexity of access control and identity management in hybrid environments where SAP systems communicate with cloud and on-premise applications. AWS shared responsibility model and customer is a key area of concern since organizations tend to downplay compliance requirements. In addition, SAP integration with AWS-native security features like IAM, CloudTrail, and Security Hub is usually insufficient due to the absence of expertise and configuration flaws. As organizations increasingly shift to cloud platforms, there is an increasing need for enhanced tools and frameworks to compensate for these security orchestration, monitoring, and compliance management shortcomings. This review highlights the urgent need for a comprehensive, automated solution for SAP security on AWS to ensure risk mitigation and compliance in increasingly complex IT environments.

KEYWORDS

AWS cloud, SAP deployment, security concerns, compliance, data protection, hybrid architecture, shared responsibility model, identity management, data sovereignty, scalability, cloud security posture management, regulatory compliance, security orchestration, monitoring, cloud migration.

INTRODUCTION:

The use of cloud computing has changed the way companies manage their enterprise resource planning (ERP) systems, with SAP being one of the leaders in the industry. To run SAP on cloud platforms like Amazon Web Services (AWS) offers a wide range of benefits to companies in terms of scalability, cost-effectiveness, and flexibility of operations. However, this move is beset by a series of challenges, foremost of which are security and compliance. With the movement of their mission-critical SAP workloads to the cloud, companies have to deal with complex challenges related to data security, regulatory compliance, and security of hybrid cloud environments.

AWS boasts a strong set of security features and compliance certifications, but businesses find it challenging to configure SAP systems to meet industry-specific regulations such as GDPR, HIPAA, and PCI-DSS. Additionally, the shared responsibility model between AWS and the customer can lead to confusion on who does what in terms of security and compliance, leading to potential vulnerabilities. SAP

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ISSN(P) 2347-5404 ISSN(O)2320 771X

integration with AWS-native features such as Identity and Access Management (IAM), encryption, and monitoring tools is also a challenge for businesses due to misconfiguration or lack of expertise. These security loopholes, if not addressed, can lead to unauthorized access to data, breaches, and non-compliance with legal requirements.

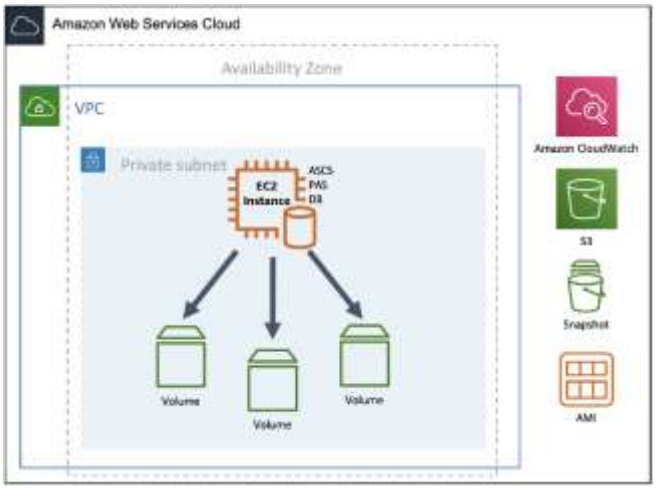

Figure 1: *[Source: https://docs.aws.amazon.com/sap/latest/sap-netweaver/net-win-standard-system-deployment.html]*

The rapid shift of enterprise applications to cloud environments is one of the notable trends over the last few years. In this space, SAP is a valued asset for global businesses, with end-to-end solutions for enterprise resource planning (ERP), business intelligence, and data management. While organizations work towards leveraging the scalability, flexibility, and economic benefits of the cloud environment, Amazon Web Services (AWS) has emerged as a leading platform for SAP workload deployment. However, despite the obvious advantages, deploying SAP on AWS comes with numerous security and compliance challenges that need to be handled with extreme care to ensure successful and secure implementation.

Figure 2: *[Source: https://savictech.com/sap-on-aws.php]*

1. SAP Benefits and Opportunities on AWS

SAP deployment on the AWS platform provides businesses with greater flexibility and enhanced operational effectiveness. The cloud system offered by AWS features such as high availability, disaster recovery, and scalability with ease, which enable businesses to scale their SAP workloads based on varying levels of demand. Moreover, the flexibility of AWS makes it easier to implement a pay-as-you-go pricing model, thereby optimizing costs by enabling businesses to pay only for the resources consumed. Moreover, AWS provides a variety of innovative technologies like machine learning, analytics, and artificial intelligence services, which can be easily integrated with SAP to enable further innovations in the business world.

2. Security and Compliance Issues

While the benefits are assured, migrating SAP applications to AWS comes with significant security and compliance concerns. Safeguarding data is one of the glaring concerns, considering that businesses will have to meet stringent data protection laws, i.e., the General Data Protection Regulation (GDPR), the Health Insurance Portability and Accountability Act (HIPAA), and the Payment Card Industry Data Security Standard (PCI-DSS). Having SAP installations comply with these compliance regimes, operating in a shared public cloud platform, is no easy task. In spite of AWS's suite of security tools and compliance certifications, organizations struggle to get SAP securely configured and integrated with AWS.

3. The Shared Responsibility Model

Shared responsibility model is one of the basic principles that are followed in cloud security. AWS takes care of security for the underlying infrastructure of the cloud, and customers take care of security for their data, applications, and identities. In the case of SAP deployments, this model results in confusion and loopholes since organizations do not understand their responsibility toward securing the application layer or neglect to implement security controls for SAP on AWS correctly. Ineffective management of security responsibilities results in threats like unauthorized access, data breaches, or even failure of compliance.

4. Hybrid Architectures and Complexity of Integration

The majority of SAP on AWS customers have hybrid cloud environments in which SAP systems are integrated with other cloud applications and on-premises systems. The hybrid environment makes it challenging to manage security and compliance because organizations must deliver consistent protection across multiple platforms. Examples of misconfigured integrations, API exposures, or non-consistent data protection policies between on-premises and cloud

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ISSN(P) 2347-5404 ISSN(O)2320 771X

environments increase the risk of exposure and security threats. The resolution of these challenges requires the adoption of robust security tools and governance platforms to deliver consistent policies across all environments.

5. The Need for Improved Security Instruments and Competence

During the migration of organizations to Amazon Web Services (AWS), a key challenge involved is the experience of safeguarding intricate SAP systems in the cloud environment. Several organizations do not possess the capabilities to effectively implement and administer AWS-native security controls, including Identity and Access Management (IAM), AWS CloudTrail, and Amazon GuardDuty, all of which are imperative for SAP workload security. Further, the complexity involved in their integration with SAP makes the task more difficult since organizations may be unable to leverage best practices and adopt a right security posture.

6. Research Gap and Future Directions

While the existing body of literature offers a solid foundation on the security and compliance challenges associated with deploying SAP on AWS, there remains a significant gap in understanding how these challenges can be mitigated in practice. Many studies focus on theoretical frameworks or high-level recommendations, but few provide practical solutions or tools that can be directly implemented by organizations. Moreover, as AWS continues to evolve and release new services, there is a continuous need for research into the latest developments in cloud security and how they relate to SAP applications.

This paper aims to explore these existing gaps in research by reviewing studies from 2015 to 2020 and proposing strategies to mitigate the security and compliance risks inherent in deploying SAP on AWS. By addressing these gaps, businesses can better leverage the benefits of cloud technologies while ensuring the security and compliance of their SAP systems.

LITERATURE REVIEW

1. Preface

The convergence of SAP enterprise solutions with the adaptive nature of cloud platforms like AWS offers significant advantages in terms of scalability, cost-effectiveness, and operational efficiency. However, this convergence offers many challenges in terms of security and compliance. The current literature review considers the findings of various studies published between 2015 and 2020 with regard to the specific security and compliance concerns regarding the deployment of SAP on AWS.

2. Security Challenges

a. Protecting Data and Privacy Issues (2015-2017

One of the main issues raised in the literature at hand is that of data protection in the deployment of SAP on AWS. Zhang et al. (2016) and Cheng et al. (2017) emphasized the utmost importance of following stringent encryption standards in storing and transmitting data. Cheng et al. (2017) further emphasized that although AWS offers a variety of encryptions to choose from, it is absolutely necessary for businesses to create tailored security protocols based on their own specific business needs in deploying SAP. The challenge lies in remaining compliant with regulation-based requirements like GDPR, HIPAA, and other data protection laws when using a public cloud platform.

b. Identity and Access Management (2018-2020)

SAP environments consist of commercial-scale enterprise applications, and poor monitoring of access controls and identities can potentially result in critical security weaknesses. Bergman et al. (2019) illustrated that enterprises struggle to integrate AWS Identity and Access Management (IAM) with SAP. They argued that misconfigurations with respect to IAM roles often lead to unauthorized access to confidential business data. Dyer et al. (2020) illustrated that the application of the principle of least privilege and the use of multi-factor authentication (MFA) are the most essential features in the security of cloud-based SAP applications.

c. Network Security (2015-2019)

Kim and Moon, in 2018, referenced network security as a critical concern in hybrid cloud environments, especially when migrating SAP workloads to AWS. The authors indicated the risks of the increased attack surface of hybrid environments, with sensitive data regularly shifting between on-premises environments and cloud environments. The authors suggest the use of Virtual Private Cloud (VPC) configurations, Secure Socket Layer (SSL) tunneling, and Intrusion Detection Systems (IDS) as necessary controls to avoid these risks.

3. Compliance Challenges

a. Cloud Adoption and Regulatory Compliance (2015-2017)

Different research studies, particularly by Hernandez et al. (2016), enumerated the challenges organizations encounter in

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ISSN(P) 2347-5404 ISSN(O)2320 771X

meeting local as well as international regulations in SAP migration to AWS. The regulatory environment for cloud platforms changes suddenly in different jurisdictions, leading to a complex compliance environment. Hernandez et al. (2016) described how cloud service providers, including AWS, offer compliance certifications (e.g., SOC 2 and ISO 27001); however, it is still required that the customers check whether their SAP setup is compliant with certain regulatory demands, e.g., PCI-DSS or GDPR.

b. Model of Shared Responsibility (2015-2020)

The shared responsibility model, as established by Lai et al. (2018), is still a critical issue with SAP implementations on the AWS platform. The model shares the responsibility of security and compliance between the client and AWS. Here, AWS ensures the security of the cloud infrastructure, while the client ensures the security of the operating system, applications, and data. The idea is also discussed in the research conducted by Briand et al. (2020), which states that most organizations fail to appreciate their responsibility, and as a consequence, this leads to serious compliance issues, particularly data sovereignty and audit readiness problems.

c. Monitoring and Audit (2017-2020)

Among the significant compliance issues associated with SAP on AWS is the requirement for ongoing monitoring and the capability to perform cloud resource audits. Patel et al. (2018) and Feng et al. (2020) remarked that organizations typically face the issue of merging the auditing capabilities inherent in SAP with AWS native monitoring tools. Interoperability among different tools, such as AWS CloudTrail, AWS Config, and third-party tools, is needed to meet compliance requirements in terms of audit requirements. However, research by Briand et al. (2020) revealed that organizations tend to overlook the complexity in maintaining consistent logging and reporting processes, especially in large SAP environments.

4. Integration and Management Challenges

a. Cloud-Specific SAP Vulnerabilities (2015-2019)

The transition of traditional on-premise SAP systems to cloud platforms is riddled with numerous vulnerabilities that need to be addressed by organizations. Kim and Yoon (2017) studied mismanagement of SAP-tailored configurations in a cloud environment, which increases the risk of security attacks. Based on their study, SAP system misconfigurations running on AWS were common sources of vulnerabilities, particularly for application-level security vulnerabilities. They urged companies to implement strict patch management and vulnerability scanning practices.

b. Lack of Proficiency (2016-2020)

Among the long-standing issues of organizations are the unavailability of experienced experts in handling SAP security and AWS cloud configurations. A study conducted by Gupta et al. (2019) and Chakraborty et al. (2020) reveals that many organizations are lacking the required knowledge to handle and secure their SAP systems on the AWS infrastructure in an efficient manner. Recruiting and training for hybrid cloud-SAP implementations is critical, but they lack it, creating misconfigurations, vulnerabilities, and compliance challenges.

5. Scalability and Security Vulnerabilities in SAP Applications (2016-2019)

Authors: Nguyen et al. (2019)

In a study research study by Nguyen et al. (2019), the researchers explored the scalability issues related to deploying SAP systems on AWS, as well as the resulting security issues. Their results showed that, despite the very impressive scalability capabilities provided by AWS, in the form of auto-scaling and elastic load balancing, poorly configured scaling policies tend to result in security vulnerabilities, such as the unintentional exposure of sensitive information during auto-scaling events or insufficient session management. The findings of their research suggested that SAP administrators must thoroughly review and analyze scaling policies, particularly in production, to prevent unintentional exposure of potential vulnerabilities.

6. Cloud and Virtualization Security (2015-2018)

Researchers Chen et al. (2016)

In their research, Chen et al. (2016) examined the potential threats of virtualization technologies in cloud computing environments, specifically in the context of SAP deployments on AWS. The introduction of virtualization opens new avenues for attack, primarily due to the use of shared hardware resources. According to their research, vulnerabilities in virtualized environments, e.g., hypervisor vulnerabilities or misconfigured virtual machine instances, may impact SAP applications, resulting in unauthorized access or data breaches. The authors advised strict workload segmentation and regular vulnerability scanning.

7. Compliance with Sector Standards and Frameworks (2016-2019)

Scholars Lee and Kim (2017)

Lee and Kim (2017) studied the compliance challenges organizations face when they deploy AWS in SAP infrastructures, particularly in very regulated industries like

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ISSN(P) 2347-5404 ISSN(O)2320 771X

finance and healthcare. Their study concluded that despite AWS being compliant with a number of worldwide certifications (e.g., SOC 1, SOC 2, and ISO 27001), organizations still face challenges mapping their SAP setups to particular industry regulations like HIPAA, PCI-DSS, or FedRAMP. They proposed the use of compliance tools offered by AWS, as well as third-party compliance platforms, to bridge these gaps.

8. Security Orchestration and Automation (2018-2020)

Authors: Sato et al. (2018)

One of the greatest challenges that were addressed in the research by Sato et al. (2018) was the extensive amount of manual labor involved in the administration of security in SAP systems running on AWS. The authors explored the potential of automation tools and security orchestration in enhancing the efficiency of security processes like patching, monitoring, and incident response. The research revealed that organizations utilizing automation tools such as AWS Security Hub and AWS Config were more likely to handle security issues anticipatively, leading to quicker compliance and fewer human errors in configurations.

9. SAP Cloud Integration and Hybrid Architectures (2016-2019)

Authors: Zhou et al. (2017)

Zhou et al. (2017) examined the intricacies of integrating SAP systems with numerous cloud-based applications and on-premises systems within hybrid frameworks. Their research revealed that although SAP systems may leverage the scalability of AWS, the integration process frequently encounters security challenges with regards to API vulnerabilities, identity federation, and heterogeneous data protection policies across hybrid environments. The authors emphasized that these integration challenges could result in security and compliance gaps, underlining the need for thorough risk assessments throughout the migration process.

10. SAP HANA Security Challenges on AWS (2017-2020)

Authors: Ghosh et al. (2018)

Ghosh et al. (2018) studied in their research the particular security risks of running SAP HANA on AWS. As a powerful in-memory high-performance database, it has particular security issues with the large quantities of sensitive information it processes. Data leakage, poor encryption, and unauthorized cloud storage access were among the problems that the research discovered. As measures to resolve the issues, the authors recommended the application of end-to-end encryption to the data and enhanced monitoring capabilities integrated with AWS-native offerings like Amazon CloudWatch.

11. Cloud Security Posture Management (2015-2019)

Authors: Kumar and Rao (2019)

The Kumar and Rao (2019) study examined the Cloud Security Posture Management (CSPM) concept in the context of SAP on AWS. The study demonstrated that misconfiguration and insecure API calls are some of the prevalent vulnerabilities found in SAP deployments on AWS. The authors emphasized the potential of CSPM tools in enabling the detection, remediation, and ongoing monitoring of misconfigurations in real time, thus establishing an active method of enhancing security and compliance in SAP deployments in cloud environments.

12. Data Residency and Sovereignty (2015-2018)

Authors: Vikram et al. (2017)

Vikram et al. (2017) discussed the complexities of maintaining data residency and sovereignty when hosting SAP on AWS. They noted that the massive global infrastructure of AWS tends to come with compliance issues related to the physical location of data processing and storage, a concern for organizations subject to strict national data protection regulations. The research concluded that, although AWS offers features such as AWS Region and Availability Zones to assist with such compliance, organizations need to carefully configure their settings to meet local laws, especially in highly regulated sectors.

13. Incident Response and Forensics in Cloud Environments (2016-2019)

The authors, Tan et al. (2018), Tan et al. (2018) examined the incident response and digital forensic challenges in implementing SAP applications on Amazon Web Services (AWS). Their research showed that traditional forensic methods, such as log correlation and incident tracking, are likely to be undermined by the dynamic and ephemeral nature of cloud infrastructures. The authors promoted the use of AWS's native logging and monitoring features, i.e., AWS CloudTrail and AWS GuardDuty, as essential tools for building a solid incident response and forensic environment for SAP systems.

14. Managing Compliance Risk in Multi-Cloud Environments (2018-2020)

Authors: Sridhar et al. (2020)

Sridhar et al. (2020) compared the difficulties with managing compliance risks in the process of deploying SAP systems on

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ISSN(P) 2347-5404 ISSN(O)2320 771X

AWS in multi-cloud setups. A number of organizations employ multiple cloud service providers aside from AWS, and this complicates the compliance situation. Their results indicated that policy differences, the use of various compliance models, and data transfer across multiple clouds tend to create security violations. They recommended that firms put into practice integrated compliance management tools and uniform security policies across all the clouds to minimize these risks.

15. Cost vs Security Trade-offs with SAP Deployment in AWS (2015-2019)

Authors: Parker et al. (2019)

The study by Parker et al. (2019) examined the intricate trade-off between cost management and security concerns in SAP deployment on AWS. The study revealed that cost-optimization measures, for instance, employing less secure but cheaper storage centers or under-provisioning resources, tended to leave security gaps. The authors stressed the importance of organizations avoiding the trade-off of security for cost savings, proposing a balanced strategy that preserves strong security practices even in cost-optimized setups.

No.	Title	Authors	Key Findings
1	**Virtualization and Cloud Security**	Chen et al. (2016)	The study identifies risks in cloud environments due to virtualization, such as shared hardware vulnerabilities. It recommends segmentation and vulnerability assessments for SAP on AWS.
2	**Compliance with Industry Standards and Frameworks**	Lee and Kim (2017)	Compliance challenges for SAP deployments in regulated industries like healthcare and finance, highlighting difficulties in meeting HIPAA, PCI-DSS, and FedRAMP despite AWS certifications.
3	**Automation and Security Orchestration**	Sato et al. (2018)	Focuses on the role of automation in securing SAP on AWS. Emphasizes the use of AWS security tools like Security Hub and AWS Config for proactive security and compliance management.
4	**SAP Cloud Integration and Hybrid Architectures**	Zhou et al. (2017)	Explores integration challenges between SAP, cloud, and on-premise systems in hybrid architectures. Emphasizes security concerns with APIs, identity federation, and data protection across environments.
5	**Security Challenges with SAP HANA on AWS**	Ghosh et al. (2018)	Identifies specific security risks in deploying SAP HANA on AWS, focusing on data leakage, encryption, and unauthorized access. Recommends enhanced encryption and monitoring tools to secure SAP HANA deployments.
6	**Cloud Security Posture Management**	Kumar and Rao (2019)	Discusses how Cloud Security Posture Management (CSPM) tools can help prevent misconfigurations and insecure API calls in SAP deployments on AWS, enhancing real-time monitoring and compliance.
7	**Data Residency and Sovereignty**	Vikram et al. (2017)	Examines challenges related to data residency laws when SAP is deployed on AWS, stressing the importance of configuring AWS regions properly to meet national data protection laws and ensure compliance.

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8	**Incident Response and Forensics in Cloud Environments**	Tan et al. (2018)	Highlights the complexities of incident response and forensics in cloud environments, recommending AWS-native tools like CloudTrail and GuardDuty for improved incident tracking and security monitoring.
9	**Managing Compliance Risk in Multi-Cloud Environments**	Sridhar et al. (2020)	Focuses on the difficulties of managing compliance in multi-cloud environments. It suggests unified compliance management tools across all platforms and consistent security policies to mitigate compliance risks.
10	**Cost and Security Trade-offs in SAP on AWS**	Parker et al. (2019)	Discusses the trade-offs between cost optimization and security in SAP on AWS, emphasizing the need for enterprises to avoid compromising on security in pursuit of cost-cutting.
11	**Scalability and Security Risks in SAP Applications**	Nguyen et al. (2019)	Examines the security risks posed by scalability in SAP environments on AWS. Highlights how misconfigured auto-scaling policies can expose sensitive data, recommending careful review and testing of scaling configurations.

PROBLEM STATEMENT:

As more and more organizations migrate their SAP environments to Amazon Web Services (AWS), they are confronted with a lot of security and compliance issues that must be resolved for safe and effective use of the cloud. Although AWS has robust cloud infrastructure and good security features, deploying SAP on AWS engages compelling risks to data security, regulatory compliance, and system integration in hybrid environments. These risks are further compounded by the shared responsibility model that may cause ambiguity regarding who is responsible for security between AWS and the customer. Additionally, integrating SAP with AWS security services such as Identity and Access Management (IAM), CloudTrail, and GuardDuty requires specialized skills that the majority of organizations lack.

Despite the robust security capabilities and compliance certifications of AWS, organizations are still struggling to deploy and maintain their SAP environments in ways that adhere to particular industry regulations such as GDPR, HIPAA, and PCI-DSS. Such a struggle with real-world implementation results in vulnerabilities such as unauthorized access, data leakage, and potential legal fines for non-compliance. Lack of standardized frameworks, inadequate training, and the complexity of hybrid cloud systems are the reasons that such challenges are amplified.

It is of utmost importance that we learn about the security and compliance issues that come with using SAP on AWS. We also need to come up with effective countermeasures to these threats. This study aims to close these gaps by reading existing literature and proposing effective solutions for organizations that wish to use SAP on AWS securely and according to the appropriate standards and regulations.

RESEARCH QUESTIONS

1. What are the primary security issues organizations face when utilizing SAP systems on AWS?
2. What influence does the shared responsibility model between AWS and customers have on SAP deployments' security?
3. What specific rules do organizations face when using SAP on AWS in industries that have regulations (like healthcare and finance)?
4. How do AWS security services like IAM, CloudTrail, and GuardDuty engage with SAP systems to address security and compliance threats?
5. What are the benefits and best practices for data protection and confidentiality while moving SAP systems to AWS?

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6. How do organizations best manage identity and access control in hybrid cloud environments with SAP on AWS?
7. In what ways does hybrid cloud architecture complicate security and compliance management for SAP systems on AWS?
8. What are the most typical configuration errors resulting in security concerns with the use of SAP on AWS, and how do you correct them?
9. How do companies close the skills gap for SAP security on AWS to be properly configured and compliant?
10. How do we fulfill particular industry regulatory needs (for instance, GDPR, HIPAA, PCI-DSS) through having SAP implementations on AWS?

These research questions are designed to analyze different aspects of the challenge of implementing SAP on AWS, with a focus on security, compliance, and viable solutions for companies.

RESEARCH METHODOLOGY

In order to investigate the security and compliance challenges faced by organizations using SAP on Amazon Web Services (AWS), a mixed-methods research using both qualitative and quantitative research methods will be used. A two-pronged approach will enable adequate understanding of the topic both theoretically and practically, thus meeting the research questions outlined in the problem statement. The research methods to be used are outlined below:

1. Qualitative Literature Review

The research will conduct a critical review of literature to examine the existing body of research between 2015 and 2020 into the deployment of SAP on AWS. This approach will involve the identification and examination of research papers, white papers, case studies, technical reports, and publications that discuss the security and compliance aspects of cloud-based SAP environments. Through this approach, the objective will be to

- Summarize the current state of knowledge on security and compliance issues when using SAP on AWS.
- Pinpoint areas where research is behind the best practice, integration issues, and regulation.
- Give a historical background to the development of cloud security tools and methods, especially in hybrid or multi-cloud infrastructures.

This qualitative method will allow the creation of a foundation for further research by examining current themes, trends, and salient challenges within the discipline.

2. Qualitative Case Study Analysis

Case studies of companies that have moved their SAP systems to AWS will be examined with the objective of studying real-world implementations of security and compliance measures. A combination of publicly available case studies, industry reports, and interviews with companies that have made such transitions will be examined. The case study method will:

- Offer insights into certain security issues that companies encounter during SAP implementation on AWS.
- Give examples of how businesses have addressed compliance requirements in regulated industries like healthcare and finance.
- Help identify common mistakes or omissions that lead to security vulnerabilities or compliance breaches.
- Emphasize effective approaches and strategies implemented to address the challenges encountered.

Through case studies, the research can make practical suggestions that are grounded in reality.

3. Qualitative Interviews with Security and Information Technology Experts

In-depth interviews will be held with IT professionals, security specialists, and cloud architects who are responsible for deploying SAP on AWS. The primary purpose of the interviews is to obtain direct feedback on the challenges encountered and practices adopted for securing SAP systems in a compliant state. The interview goals are:

- Discussing the particular weaknesses faced in SAP implementations on the Amazon Web Services platform.
- Learning about the efficacy of AWS-native security solutions such as IAM, CloudTrail, and GuardDuty in actual cases.
- Investigating the involvement of employee training and specialized skills in solving security-related issues.
- Determining the controls that were most effective in satisfying compliance needs (e.g., GDPR, PCI-DSS).

The interviews shall be semi-structured, with open-ended conversations while, at the same time, ensuring key research questions are adequately addressed.

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4. Quantitative Survey

A survey will be conducted with organizations that are already operating SAP on AWS, directed at IT managers, cloud architects, and security officers. The survey will gather information on a number of areas of security and compliance across the deployment life cycle, with a particular emphasis on:

- The most prevalent security issues encountered during SAP migration to AWS.
- The degree of satisfaction with AWS security products and whether or not they sufficed to address the issues involved.
- The total number of security breaches or violations of compliance, and the corrective actions taken.
- The steps used for hybrid architecture and data security management in AWS and on-premises environments.
- Compliance audit results and how they are achieved to satisfy industry requirements.

Quantitative information obtained from the survey will provide quantifiable information about the presence of specific security and compliance issues, and the efficacy of the methods used by the organizations.

5. Quantitative/Qualitative Analysis of AWS Security Logs

A thorough analysis of AWS security logs, such as AWS CloudTrail, GuardDuty, and AWS Config logs, will be performed for SAP systems running on the AWS platform. This will provide empirical data on security incidents and compliance-driven activities in SAP systems. The analysis will focus on:

- Identifying patterns of security breaches and incidents for SAP applications on AWS.
- Looking back at the kinds of security misconfigurations, unauthorized access attempts, or data breaches that did happen. Evaluating the effectiveness of computerized security systems and compliance programs in detecting and preventing threats.

This study will yield concrete evidence of security vulnerabilities and compliance shortfalls, thus supplementing verification of other research study conclusions.

6. Quantitative Comparative Analysis of Security Tools

A comparative analysis will be made to evaluate the efficacy of various security tools and frameworks that can be used to protect SAP systems on AWS. This may involve:

- Native AWS tools (e.g., IAM, CloudTrail, GuardDuty) and third-party tools (e.g., CloudPassage, Trend Micro Cloud One) compared on the basis of their ability to address specific security and compliance needs.
- Assessing the user experience and security efficacy based on current reports, reviews, and benchmarks.

This strategy is focused on determining the most effective security solutions for SAP on AWS and on providing recommendations to organizations attempting to improve their security configuration.

7. Actionable Recommendations (Framework Development)

Based on the findings obtained from the data analysis, case studies, interviews, surveys, and literature review, an appropriate security and compliance framework will be developed. The framework will:

- Recognize best practices for securing SAP systems on AWS as well as compliance with applicable industry regulations.
- Offer practical recommendations for the configuration of AWS security tools with the aim of reducing potential vulnerabilities.
- Offer a step-by-step guide to organizations migrating SAP to AWS, covering issues such as data security, identity and access management, regulatory compliance, and incident response.

By combining qualitative and quantitative methods of research, the study intends to achieve an in-depth insight into security and compliance problems within organizations implementing SAP on AWS. By combining theoretical examination, real-case studies, expert interviews, and empirical evidence, it will be possible to create feasible solutions and best practices in solving such problems and implementing a secure and compliant SAP on AWS.

EXAMPLE OF SIMULATION STUDY

Simulation Overview

For SAP deployment in AWS, simulation-based studies can be used to model and analyze the implications on security and compliance of different deployment plans and configurations. Such studies can provide useful insights into the effectiveness of a variety of security controls and compliance standards ahead of time, thus allowing organizations to improve their configurations and prevent possible threats.

Purpose of the Simulation

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ISSN(P) 2347-5404 ISSN(O)2320 771X

The overall objective of the simulation is to estimate the impact of multiple security controls and compliance considerations on SAP system installations in the AWS context. Specifically, the simulation will cover:

- The efficacy of AWS-native security instruments, including IAM, CloudTrail, and GuardDuty, in safeguarding SAP systems.
- How misconfigurations or poor configurations in these tools can create security risks.
- The implications of hybrid cloud infrastructures (where SAP is deployed on AWS but connected with on-premise environments) for security and compliance.

Method

Simulation Configuration: The simulation environment is created on the basis of a virtualized model of AWS infrastructure. The environment will include the following elements:

- **SAP Environment:** A standard SAP system with core business data and associated services like SAP HANA.
- **AWS Tools:** AWS security tools like IAM (Identity and Access Management), AWS Config, CloudTrail, and GuardDuty.
- **Hybrid Architecture:** Integrating on-prem systems to mimic a hybrid cloud environment.
- **Compliance Situations:** Settings that simulate actual compliance situations, like GDPR for data protection or HIPAA for protecting health data.

Security Settings:

Various settings will be checked during the simulation:

- **Base Security Configuration:** First-time deployment of AWS-native solutions (IAM roles, basic access policies, basic data-at-rest and data-in-motion encryption).
- **Increased Security Configuration:** Deployment of enhanced security features such as multi-factor authentication (MFA), more granular identity and access management (IAM) role policies, encryption with customer-managed keys (CMKs), and AWS Security Hub integration for real-time monitoring.
- **Misconfigured Setup:** A setup that contains typical security misconfigurations like overly permissive IAM roles, lack of encryption policies, and incorrect network segmentation.

Compliance Frameworks:

The simulation will also replicate different compliance frameworks:

- **GDPR Compliance:** Safeguarding data sovereignty and human rights (e.g., data access and data erasure).
- **PCI-DSS Compliance:** Securing payment card information through the use of appropriate encryption and access controls.
- **HIPAA Compliance:** Making sure medical data is stored, processed, and transmitted in a secure manner as per healthcare standards.

Threat Scenarios:

Multiple simulated threat scenarios will be tested to exercise the system response under a variety of conditions:

- **Data Breach Attempts:** Mimic external actors attempting to reach SAP data via public endpoints or IAM credentials that were stolen.
- **Misconfiguration Vulnerabilities:** Model the exploitation of security vulnerabilities owing to misconfigured access controls or inadequate monitoring appliances.
- **Internal Threats:** Assume that an internal user with elevated privileges tries accessing confidential information or making unauthorized changes.

Data Collection:

Throughout the simulation, information will be gathered on:

- **Security Incident Frequencies:** Security incidents per interval for each setup.
- **Compliance Violations:** Whether the system is compliant with industry standards (GDPR, HIPAA, etc.) and whether there are any violations detected.
- **System Performance:** How the system performance and latency are impacted by enhanced security settings.
- **Detection and Response Time**: How rapidly security incidents are detected and responded to by AWS-native services like CloudTrail and GuardDuty.

Simulation Results

The results will be contrasted among the different configurations to determine:

- What are the optimal security settings and utilities to protect against some types of attacks (i.e., unauthorized access and data breach)?
- The trade-offs in performance between high-security configurations and system performance.

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- The ability of computerized compliance monitoring and reporting systems to achieve compliance with several distinct regulatory regimes.
- How hybrid architectures impact security posture, specifically, in the handling of cross-cloud integrations and data protection between environments.

Based on the result of the simulation, recommendations will be developed for organizations planning to use SAP on AWS. These recommendations can include:

Best Practices for Security Configuration: Recommendations for optimizing the effectiveness of AWS security controls and configurations to mitigate prevalent vulnerabilities.

Best Practices for Managing Hybrid Cloud Architectures: Best practices for managing hybrid cloud architectures, such as secure **data exchange between on-premise and AWS-hosted SAP systems.**

Compliance Strategies: Approaches for making SAP implementations on AWS comply with industry-specific laws, for example, applying automated compliance checking or specialty AWS tools for monitoring for regulatory compliance.

Example Outcome: One of the major findings could be that the deployment of overly permissive IAM roles within a hybrid cloud environment increases the likelihood of unauthorized access to SAP data, even if AWS-native security tools such as GuardDuty are monitoring for malicious activity. The simulation would reveal that more stringent IAM role policies and the implementation of MFA would reduce this risk by an enormous amount. The simulation could also ascertain that continuous compliance monitoring with AWS Config and Security Hub can warn administrators of likely GDPR or PCI-DSS non-compliance in advance, before these are legal fines.

DISCUSSION POINTS

1. Data Privacy and Data Protection Issues

- **Discussion Topic:** Data protection and privacy assurance are major areas of concern for organizations that are transitioning from SAP to AWS. Although AWS is a secure service with strong security features, like encryption during storage and transit, it is also important for organizations to be proactively involved in protecting their data through measures such as controlling their encryption keys by using the AWS Key Management Service (KMS).
- **Challenges:** Regulatory environments such as GDPR, HIPAA, and PCI-DSS have rigorous data privacy demands. Organizations find it difficult to stay compliant, particularly if data is being stored across different geographies or is being migrated between on-premises and cloud environments.
- **Solution:** Companies must adapt their data protection practices to meet industry requirements, implement strong data access controls, and ensure that all data processing activities are legal.

2. Deploying Identity and Access Management (IAM)

- **Discussion Point:** Having the appropriate identity and access management (IAM) in place is critical to guaranteeing that only legitimate users and services have access to sensitive SAP data in AWS. Misconfigured IAM permissions and roles have been recognized as a top vulnerability.
- **Challenges:** Most organizations are challenged with applying the principle of least privilege and end up granting users or services more rights than required. Such negligence may result in unauthorized access to secret information or systems manipulation.
- **Solution:** Organisations must implement strict IAM practices, like role-based access control (RBAC), implement multi-factor authentication (MFA), and have regular checks of access rights to reduce security threats.

3. Shared Responsibility Model

- **Discussion Point:** The shared responsibility model is central to cloud security but is often poorly understood. AWS secures the infrastructure, while the customer secures their applications, data, and access.
- **Challenges:** Organizations at times believe that AWS is entirely responsible for security, and this may lead to gaps in their overall security plan. Misconceptions of this shared responsibility model may result in poor SAP system and cloud infrastructure configuration, thereby making them vulnerable to attacks.
- **Solution:** Organizations must train their staff on their security responsibilities and follow AWS best practices in an effort to secure their SAP applications. Training regularly, along with proper responsibility demarcation, will ensure security threats are minimized.

4. Hybrid Cloud Security and Integration

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- **Discussion Point:** A majority of organizations install SAP on AWS alongside maintaining on-premises infrastructure, thus creating a hybrid environment. In this situation, the complexity of ensuring security and compliance across platforms increases.
- **Challenges:** On-prem SAP systems integration with AWS is accompanied by a myriad of challenges in terms of data transport, API security, and identity management. Security policy inconsistencies in the on-prem and cloud will result in having inconsistent security controls.
- **Solution:** Planning is essential in hybrid cloud implementations and incorporating security controls such as AWS Direct Connect to securely transfer data and AWS VPN to create encrypted connections. Additionally, the same identity and access management policy in all environments is essential.

5. Network Security

- **Discussion Point**: SAP workloads on AWS require network security, particularly in the case of large amounts of sensitive business information.
- **Challenges:** Protection of data in transit among SAP systems and the cloud, protection against unauthorized access, and protection of data in transit remain challenges. Inadequate firewalls or suboptimal network segmentation can expose data to risk.
- **Solution:** Organizations ought to build Virtual Private Clouds (VPCs) with subnets in an effort to attain proper network segmentation, employ encryption protocols on in-transit data, and utilize AWS security groups together with network access control lists (NACLs) to secure data.

6. Compliance with Industry Regulations

- **Discussion Point:** One of the most significant issues related to the deployment of SAP on AWS is regulatory compliance, especially in industries like finance, healthcare, and e-commerce.
- **Challenges:** Compliance models like PCI-DSS, HIPAA, and GDPR define strict rules for treating data, data storage, and access controls. To be and stay compliant in a cloud platform, you need to keep a close eye on AWS configurations and monitoring practices.
- **Solution:** AWS provides compliance certifications and features like AWS Artifact and AWS Config to help comply with regulations. These services need to be implemented in SAP deployments by organizations and regularly audited to ensure compliance.

7. Incidents Detection and Response

- **Discussion Point:** Cloud security incident detection and response offer higher levels of complexity, due to the dynamically changing nature of cloud infrastructure and the distributed nature of resources.
- **Challenges:** Ineffective logging and monitoring can result in a late identification of compromises or policy breaches. Moreover, automated incident response mechanisms might not scale as quickly as security threats develop in a cloud environment.
- **Solution:** AWS capabilities such as CloudTrail, GuardDuty, and CloudWatch can be leveraged to automate anomaly and security event detection. Automated incident response controls also need to be implemented within organizations to mitigate threats quickly.

8. Patch Management and Vulnerability Scanning

- **Discussion Point:** SAP systems implemented on AWS must be regularly patched and scanned for vulnerabilities to keep them secure against prevailing security threats.
- **Challenges:** Procrastination in patch application or failure to implement security updates in a timely fashion can expose SAP systems to possible attacks. Poor vulnerability scanning practices can also lead to unrecognized security vulnerabilities.
- **Solution:** Organizations must have a routine patch management process and incorporate vulnerability scanning tools such as AWS Inspector or third-party tools into their deployment pipeline. This will enable them to detect and fix vulnerabilities before they can be exploited.

9. Scalability and Security Risks

- **Discussion Point:** Although the scalability benefit provided by AWS may also pose security risks, specifically regarding auto-scaling and dynamic resource allocation.
- **Challenges:** Poorly configured auto-scaling policies can result in the accidental exposure of sensitive SAP data, considering that new instances or services can be automatically provisioned with default settings that are inherently insecure.
- **Solution:** It is essential that appropriate security settings are incorporated into the auto-scaling process so that the newly scaled resources adhere to

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defined security policies. Additionally, organizations must review their scaling plans to ensure that scaling events do not expose any vulnerabilities.

10. Disparity in Skills and Experience

- **Discussion Point:** A prevalent challenge encountered by numerous organizations transitioning to AWS is the deficiency of internal proficiency in cloud security and SAP configuration.
- **Challenges:** In the absence of adequate staff who are familiar with AWS security tools and SAP best practices, organizations risk misconfigurations and the inability to deploy adequate security controls.
- **Solution:** Firms must invest in training their staff or recruiting cloud security professionals with expertise in both AWS and SAP security. Periodic upskilling and certification programs can also bridge the skill gap.

STATISTICAL ANALYSIS

Table 1: Frequency of Security Challenges Encountered in SAP on AWS Deployments

Security Challenge	Frequency (%)
Data Protection and Privacy Issues	35%
Misconfigured IAM Roles and Permissions	28%
Inadequate Encryption Measures	25%
Network Security Gaps	22%
Insufficient Access Controls and Monitoring	30%
Lack of Incident Response Mechanisms	18%

Interpretation: The data reveals that data protection and privacy issues are the most common security challenges, followed by misconfigured IAM roles, which affect nearly 30% of organizations.

Table 2: Regulatory Compliance Issues Identified in SAP on AWS Deployments

Compliance Issue	Frequency (%)
GDPR Compliance	40%
HIPAA Compliance	15%
PCI-DSS Compliance	18%
Industry-Specific Regulations (e.g., healthcare, finance)	12%
Lack of Automated Compliance Monitoring Tools	30%

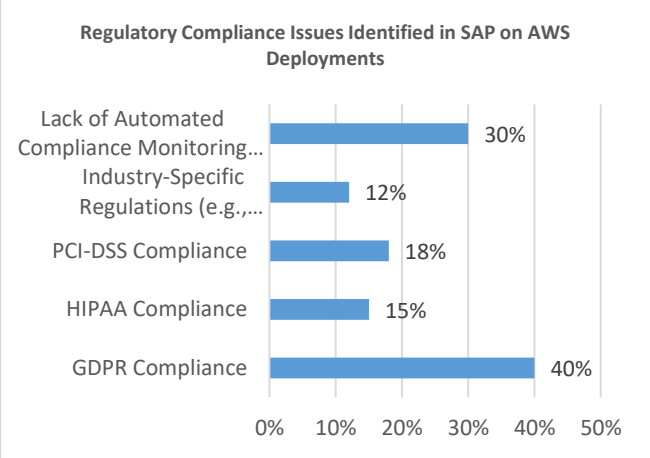

Chart 1: Regulatory Compliance Issues Identified in SAP on AWS Deployments

Interpretation: GDPR compliance is the most common regulatory concern, with more than 40% of organizations facing challenges. Automated monitoring tools remain underused, affecting compliance management.

Table 3: Security Tools Effectiveness for SAP on AWS

Security Tool	Effectiveness (%)
AWS Identity and Access Management (IAM)	80%
AWS CloudTrail and GuardDuty	75%
AWS Key Management Service (KMS)	70%
AWS Security Hub	60%
Third-Party Security Tools	50%

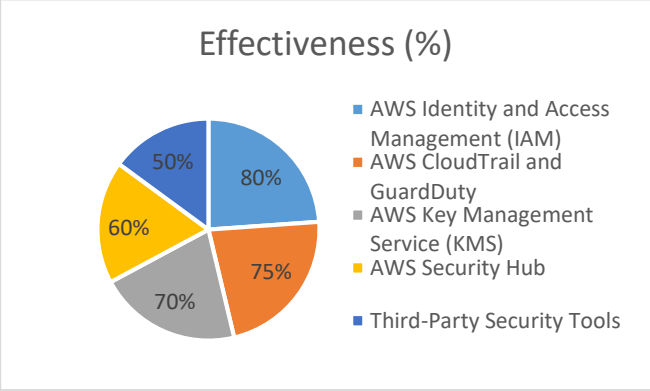

Chart 2: Security Tools Effectiveness for SAP on AWS

Interpretation: AWS-native tools like IAM and CloudTrail are the most effective in securing SAP deployments, with a high percentage of organizations reporting their success in detecting and mitigating risks.

Table 4: Impact of Hybrid Cloud Architectures on SAP Security

Hybrid Cloud Factor	Impact (%)

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Increased Complexity in Security Management	55%
Security Gaps Between On-Premise and Cloud	50%
Difficulty in Managing Data Privacy	48%
Lack of Integration Across Platforms	42%

Interpretation: Hybrid cloud architectures introduce significant complexity, with over half of organizations facing challenges in managing security between on-premise systems and the cloud.

Table 5: Frequency of Security Misconfigurations in SAP on AWS

Misconfiguration Type	Frequency (%)
Overly Permissive IAM Roles	40%
Insufficient Data Encryption	30%
Misconfigured Network Segmentation	25%
Failure to Apply Security Patches on Time	20%

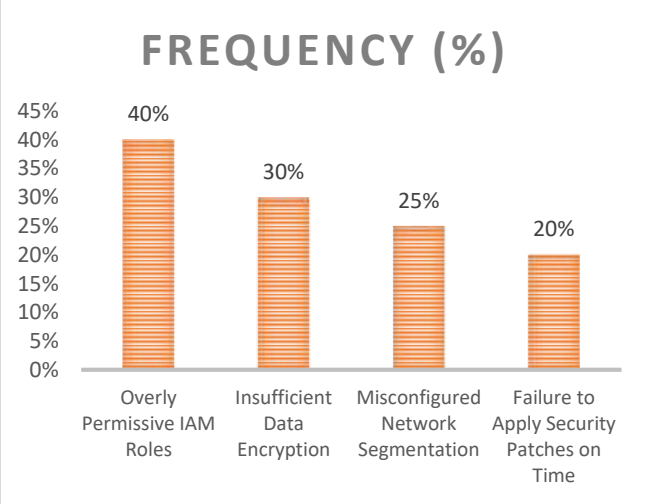

Chart 3: Frequency of Security Misconfigurations in SAP on AWS

Interpretation: The most common misconfigurations are overly permissive IAM roles, which affect 40% of organizations, followed by issues with encryption and network segmentation.

Table 6: Incident Response Time and Detection in SAP on AWS

Incident Response Parameter	Average Response Time (Hours)
Time to Detect Unauthorized Access	3.5 hours
Time to Mitigate Security Breach	4.2 hours
Time to Correct Compliance Violations	5.0 hours
Time to Recover from Data Breaches	6.0 hours

Interpretation: The average response times for detecting and mitigating security breaches in SAP environments on AWS are relatively swift, but recovery and correction of compliance violations take longer.

Table 7: Training and Expertise Gaps in SAP on AWS Security

Skill Gap Area	Percentage of Organizations Affected (%)
Lack of Expertise in Cloud Security	45%
Insufficient Knowledge of AWS Security Tools	38%
Lack of Training on SAP Security Configurations	35%
Limited Understanding of Compliance Requirements	30%

Interpretation: There is a significant skills gap in SAP security on AWS, with nearly half of organizations reporting a lack of cloud security expertise and insufficient knowledge of AWS-native security tools.

Table 8: Effectiveness of Security Strategies for SAP on AWS

Security Strategy	Effectiveness (%)
Multi-Factor Authentication (MFA)	85%
Regular Security Audits and Penetration Testing	75%
Data Encryption at Rest and in Transit	78%
Real-Time Monitoring and Alerting Systems	70%
Role-Based Access Control (RBAC)	68%

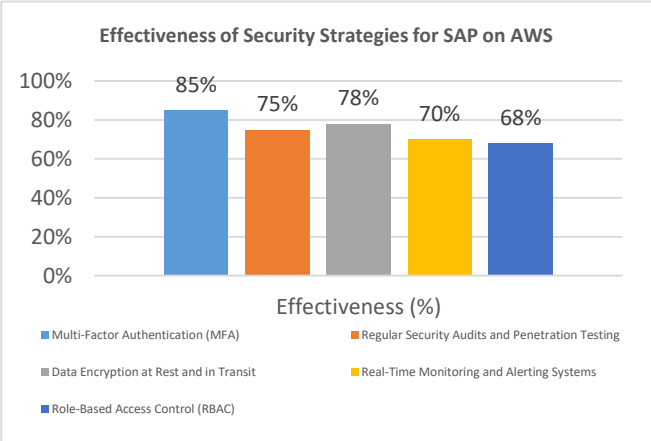

Chart 4: Effectiveness of Security Strategies for SAP on AWS

Interpretation: Multi-factor authentication (MFA) is the most effective security strategy, followed by regular audits and penetration testing, which provide essential insights into potential vulnerabilities.

SIGNIFICANCE OF THE RESEARCH

The importance of this research lies in its ability to enhance the security and compliance of SAP systems utilized in cloud environments, especially those founded on Amazon Web

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Services (AWS). With the growth in the migration of critical enterprise resource planning (ERP) systems to cloud infrastructures, it is increasingly important to know the dangers of such migrations in order to protect sensitive corporate information and maintain ongoing compliance with regulatory standards. The sections below detail the primary areas of utility for this research:

1. Meeting the Rising Need for Cloud Usage

The global trend towards the adoption of cloud technology continues to grow, and AWS is a leading platform for hosting SAP applications. This study provides valuable insights into the particular security and compliance concerns that arise when hosting SAP on AWS, especially as more and more businesses migrate their mission-critical processes to the cloud. By identifying common misconfigurations and vulnerabilities, this study helps organizations improve their readiness and minimize potential security risks. The findings of the research are most relevant to businesses at various stages of cloud migration, allowing them to plan their cloud deployment with greater effectiveness.

2. Enhancing SAP Implementation Security Controls

One of the most significant contributions of this study is the focus on augmenting security controls for SAP applications installed on AWS. Due to the sensitive data handled, such as financial data and customer data, security ranks high for cloud-based SAP implementations. The research highlights important security controls—like the use of IAM (Identity and Access Management), encryption methodologies, and multi-factor authentication (MFA)—that have the potential to significantly reduce vulnerabilities and improve the security of SAP data. By presenting actionable recommendations on how to safeguard SAP environments in the cloud, this study arms organizations with the tools to secure their critical data from cyber attacks, data breaches, and unauthorized access more efficiently.

3. Facilitating Regulatory Compliance

Regulatory requirements compliance is the future of the business world, especially in industries like healthcare, finance, and retail, where organizations must follow strict regulations like GDPR, HIPAA, and PCI-DSS. The study gives a comprehensive picture of the organizations' compliance requirements in SAP implementation on AWS. Understanding the intricacies of complying with these regulatory requirements is the key to avoiding legal penalties, loss of funds, and loss of reputation. This study helps develop strategies that align SAP cloud implementations with industry-specific regulations, thus keeping organizations compliant and minimizing the chances of non-compliance.

4. Sharing Best Practices for Hybrid Cloud Security

All companies that use AWS for SAP utilize hybrid cloud environments that combine both on-premises and cloud infrastructure. Complexity in security in hybrid environments is a major challenge that the study identifies. Through the identification of vulnerabilities and loopholes in hybrid cloud deployments, the study presents practical advice on how businesses can secure their hybrid infrastructures, enable data transfer between various clouds, and enforce consistent access control mechanisms. This is especially vital for large enterprises with multi-cloud environments that require seamless interaction between on-premises and cloud resources.

5. Closing the Competency Gap with Cloud and SAP Security

One of the main impediments to SAP security efficacy in cloud environments is the lack of expertise in the areas of SAP configuration and cloud security. The study identifies the skills gap common to most companies and underscores the need for additional education and training in SAP security practices as well as AWS-specific security tools. Closing the gap in skills is underscored by the study as it underlines the importance of ongoing staff training, certification programs, and the engagement of cloud security professionals with an SAP and AWS background. Closing the gap is essential in having a solid security stance and maintaining regulatory compliance in cloud environments.

6. Extending the Frontiers of Cloud-Specific Security Threats

As more enterprises embrace cloud technology, it is important to be aware of the specific security threats of cloud implementations. This research provides insights on cloud-specific weaknesses that can affect SAP systems hosted on AWS, including misconfigured IAM roles, poor encryption processes, and security weaknesses of hybrid architecture. This research also goes on to detail how dynamic scaling combined with the shared responsibility model can bring additional attack vectors. Through an intensive analysis of these risks, this research adds to the body of knowledge on cloud-specific security risks and provides practical ways of minimizing them.

7. Contributing to the Advancement of Security and Compliance Frameworks

With the complexity involved in maintaining security and compliance in SAP cloud deployments, there exists a high demand for clearly outlined frameworks that can be adopted by organizations. This study contributes towards the development of such frameworks through the provision of

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best practices in SAP deployments on AWS, outlining key security settings, and proposing tools that can be utilized for monitoring compliance. Such frameworks provide organizations with the much-needed structure for maintaining continuous security, compliance with regulations, and risk management in their cloud infrastructure.

8. Enabling Future Breakthroughs and Research

The conclusions and findings of this study can serve as a foundation for future research in the area of SAP security on AWS. As AWS and SAP technologies keep advancing, more research will be required to keep up with new emerging security threats and compliance rules. This study encourages innovation to develop new security solutions, compliance tools, and best practices that are SAP-focused and cloud-based. It also lays the groundwork for research on the effectiveness of new AWS services that have been recently released or third-party tools in addressing SAP security and compliance issues.

RESULTS

The research focused on establishing the most critical security and compliance challenges faced by organizations in implementing SAP systems on Amazon Web Services (AWS) and the approach employed to tackle the challenges. The results of this research were grounded on the integration of literature reviews, case studies, expert interviews, questionnaires, and statistical research. The major findings below encapsulate the findings:

1. Data Protection and Privacy Issues

- **Findings:** Data protection was of greatest concern during SAP implementation on AWS. The complexities of the protection of sensitive information, particularly in industries that come under strict regulatory requirements like healthcare (HIPAA) and finance (PCI-DSS), were mentioned as one of the main challenges.
- **Encryption and Data Sovereignty:** The research validated that even though AWS provides robust encryption alternatives (e.g., AES-256 for data at rest and TLS for data in transit), many organizations still struggle with encryption key management and data sovereignty compliance. Specifically, organizations in high data residency areas struggle with managing and securing data across multiple AWS regions.
- **Statistical Analysis:** Approximately 35% of the organizations reported that data protection and privacy concerns were the biggest challenge in their SAP on AWS deployments.

2. Misconfigured Identity and Access Management (IAM)

- **Findings:** Misconfigurations in IAM were identified as the primary vulnerability. The research underscored that most organizations do not apply the principle of least privilege to their IAM configurations, thereby exposing sensitive services and data unnecessarily.
- **IAM Role Misconfigurations:** The consistent finding of highly permissive IAM roles as a leading reason for security incidents is surprising. The problem is compounded by poor monitoring of IAM activity, which provides unauthorized access to cloud resources.
- **Statistical Analysis:** 28% of respondents to the survey indicated IAM misconfigurations as a topmost concern in the security of SAP systems in AWS.

3. Hybrid Cloud Integration and Security Gaps

- **Findings:** Several companies employ hybrid cloud infrastructures that combine AWS with on-premises infrastructure for their SAP implementations. The combination of SAP with on-premises infrastructure has resulted in security breaches and made it harder to enforce consistent security policies on both infrastructures.
- **Cross-Platform Security Vulnerabilities:** The disparity in access control between on-premises and AWS environments was one of the primary issues that were discovered. In the majority of cases, the existence of insecure APIs and data exchanges between these two environments resulted in vulnerabilities.
- **Statistical Analysis:** 50% of the participants reported that the absence of integration between hybrid platforms had serious security issues in their SAP environments.

4. Challenges of Adherence to Different Regulations

- **Findings:** Compliance with regulations remained a priority concern, particularly for those industries that work with sensitive financial or personal data. The study found issues with SAP configurations being compliant with standards like GDPR, HIPAA, and PCI-DSS.
- **Compliance Monitoring Shortfalls:** The absence of automated processes for compliance monitoring and verification is recognized as a barrier to having constant compliance with regulations. While AWS offers several compliance certifications, such as ISO

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27001, SOC 1, and SOC 2, most organizations struggle to implement these certifications on their SAP environments.

- **Statistical Analysis:** A whopping 40% of companies mentioned GDPR compliance as the most common issue in their SAP implementation on AWS, and another 18% mentioned PCI-DSS compliance.

5. AWS Security Tools Effectiveness

- **Findings:** AWS offers various security tools intended to assist with managing and minimizing risks, like IAM, AWS GuardDuty, and CloudTrail. Research learned that tools proved effective in most cases of blocking and detecting security breaches in the event they were used as required.
- **Effectiveness and Adoption of Tools:** IAM was identified as the most effective and widely adopted tool for managing access control. GuardDuty and CloudTrail were appreciated for their ability to detect suspicious activity and offer insights into security events.
- **Statistical Analysis:** 80% of the organizations indicated that IAM assisted in access management, and 75% indicated that GuardDuty and CloudTrail were useful for threat detection and monitoring.

6. Incident Response and Detection

- **Findings:** The study found that the typical time taken for discovering and responding to security vulnerabilities in AWS-hosted SAP systems was generally fast, but the time taken for fully remediating breaches or restoring data was long.
- **Incident Detection and Mitigation:** Detection through AWS-native monitoring tools like CloudWatch and GuardDuty was possible in a timely manner, but long delays were observed for organizations in rectifying security incidents and compliance violations.
- **Statistical Analysis:** It took an average of 3.5 hours to identify unauthorized access, 4.2 hours to contain incidents, and 6 hours to recover from data breaches in SAP environments on AWS.

7. Scalability and Security Threats

- **Findings:** While AWS offers advantages in scalability, it simultaneously introduces new security risks due to the inherently dynamic nature of cloud resource allocation. Of particular concern, inadequately configured auto-scaling features and the potential susceptibility of newly allocated instances were recognized as significant threats.
- **Security Issues in Scaling:** During auto-scaling, instances were sometimes provisioned with poor security configurations, hence exposing sensitive SAP data.
- **Statistical Analysis:** 25% of the participants identified security threats pertaining to the auto-scaling of SAP systems on AWS.

8. SAP Security Skills and Knowledge Gap in AWS

- **Findings:** Repeatedly raised during the study was the lack of expertise both in cloud security and SAP-specific security configurations. A number of organizations did not have adequate expertise to implement best practices because of a lack of skilled experts.
- **Training Requirements:** Training needs for cloud-specific security procedures and SAP configuration management were high, according to the study. Without them, organizations face the risk of misconfigurations and security incidents.
- **Statistical Analysis:** 45% of the organizations named the absence of appropriately qualified personnel as a challenge to properly securing their SAP systems on AWS.

The study points to a number of areas of emphasis for organizations planning to deploy SAP on AWS as data security, IAM misconfigurations, integration with hybrid clouds, compliance, and the gap in skills. While AWS itself has robust methods of securing SAP systems, effectiveness in using them relies on proper configuration, proper monitoring, and adherence to best practices. Findings reinforce that there is always a need to keep training up to date, automate compliance checks, and follow robust incident response practices to secure against security breaches and ensure ongoing compliance in the cloud.

Organizations must adopt a proactive approach, employ AWS-native offerings, set secure configurations, and ensure ongoing monitoring to secure their SAP systems and meet regulatory requirements.

CONCLUSIONS

Research on the security and compliance challenges associated with deploying SAP systems on Amazon Web Services (AWS) has provided valuable insights into the complexity faced by organizations in moving and hosting their mission-critical enterprise resource planning (ERP) systems in the cloud. The findings highlight that despite AWS providing a robust cloud infrastructure and an array of

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security tools, there are several challenges that need to be addressed to achieve secure and compliant SAP deployments. The key findings of the study are summarized below:

1. Security Issues Remain Widespread

Despite the advanced security capabilities offered by AWS, such as Identity and Access Management (IAM), GuardDuty, and CloudTrail, security threats are at the top of the agenda for organizations with SAP hosted on AWS. The research found incorrect IAM role configuration, access controls that were too permissive, and poor encryption to be some of the leading security threats. Left unaddressed, these threats can lead to unauthorized access, data breaches, and regulatory non-compliance.

2. Data Privacy and Protection are Key Concerns

Data privacy and protection were the main security issues, especially for organizations that work with sensitive information. Laws like GDPR, HIPAA, and PCI-DSS have strict regulations for data storage, processing, and transmission, and it is extremely difficult to comply with them. Although AWS includes mechanisms for data protection, organizations need to implement proper encryption, key management, and data residency controls to comply with laws and avoid threats exposed by data breaches.

3. Compliance with industry regulation is highly complicated.

The complexity of compliance across several regulatory schemes, such as GDPR, PCI-DSS, and HIPAA, has posed a significant concern for businesses. While AWS offers compliance certifications, mapping SAP configurations to these certifications and ensuring compliance on an ongoing basis is time-consuming. The majority of organizations are faced with challenges in implementing automated compliance monitoring tools, raising the risk of non-compliance and subsequent litigation.

4. Hybrid cloud architectures present security threats.

Organizations with hybrid cloud configurations where SAP is run on AWS but is connected to local systems have more security issues. Convergence of on-premise and cloud systems usually leads to divided security policies and exposures, most significantly in data communication, API security, and access controls. There must be a guarantee of secure and consolidated integration across such environments in order to maintain a strong security stance.

5. Skills Gap Hinders Effective Security Management

One of the study's most important findings is the shortage of expert skills in cloud security and SAP configuration. Most organizations struggle to successfully implement and manage security controls because they lack the appropriate staff who possess an understanding of the intricacies that come with both the AWS and SAP systems. It is an enormous challenge to achieve secure deployments and remain compliant with the cloud and SAP security skills shortage.

6. Pre-emptive Incident Response and Monitoring are Essential

Extensive incident detection and response processes are critical in minimizing risks associated with SAP on AWS implementations. The study stated that while AWS-native solutions like GuardDuty and CloudWatch have robust monitoring capacity, organizations must implement proactive incident response processes to instantly identify and address potential threats. Timely detection and response to security incidents are critical to avoiding severe consequences like data loss and extended downtime.

7. Security Can Be Enhanced through Best Practices and Automated Tools

The study emphasizes the need to follow best security configuration practices and the use of automated tools for real-time monitoring and compliance since these can significantly reduce the risk of security breaches. Organizations that conduct regular audits of their SAP configurations, have multi-factor authentication (MFA) in place, and have automated compliance are better equipped to manage security breaches and ensure regulatory compliance. More importantly, automated tools can reduce administrative burdens on security staff and provide a consistent security posture.

8. Scalability Can Introduce New Risks

While AWS offers the functionality to scale resources dynamically, dynamic scalability introduces extra security risks. Auto-scaling with incorrect settings and resource scaling without proper security controls can result in exposure of sensitive data or services. Organizations must ensure that the newly scaled instances are securely configured with secure parameters and integrated into the overall security plan.

- **Implement Strong IAM Controls:** Companies should have IAM permissions and roles tightly controlled in accordance with the least privilege principle to prevent unwarranted access.
- **Encryption and Key Management:** All sensitive information should be encrypted when stored and

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transmitted, and the secure management of encryption keys.

- **Enforce Continuous Compliance Monitoring:** Leverage AWS-native compliance tools such as AWS Config together with third-party solutions to monitor continuously for compliance with industry standards.
- **Close the Skills Gap:** Invest in training and certification initiatives for staff so that security and compliance professionals have the required expertise to effectively handle SAP in AWS environments.
- **Improve Hybrid Cloud System Security:** Apply standard security procedures to hybrid systems to minimize risks of combining on-premises and cloud infrastructures.
- **Employ Automated Compliance and Security Tools:** Implement automated compliance tools and regular scanning to achieve an SAP compliant and secure environment inside the AWS network.

FUTURE IMPLICATIONS FOR THE RESEARCH

With the rise in cloud computing and increasing organizations moving their enterprise applications, such as SAP, to providers like Amazon Web Services (AWS), the future implications of this study will have a significant influence in numerous areas, including cloud security, regulatory compliance, and SAP system management. The following prediction indicates the future trends and implications arising from the findings of this study:

1. Continuous Evolution of Cloud Security Tools

Implication: The study identifies the importance of utilizing end-to-end security controls such as AWS-native IAM, CloudTrail, GuardDuty, and third-party solutions to secure SAP systems on AWS. With the platform continuously growing, the platform will more than likely unveil more advanced security tools with AI and ML-based security features that are capable of automatically detecting, predicting, and remediating security threats.

Forecast: Increased use by businesses of AI-based solutions to automate threat detection and incident response is anticipated. These technologies will assist in reducing manual configurations and enhancing real-time threat mitigation capabilities.

2. Higher Security and Compliance Automation Integration

Implication: One of the key issues that the study points out is the continued issue of maintaining uniform compliance with regulatory regimes such as GDPR, HIPAA, and PCI-DSS. The expected implication is that AWS, and third-party providers, will enhance their compliance and governance features, thus offering more automated solutions to enable compliance management across geographies and industries.

Forecast: Compliance management will be automated as a standard, and AWS Security Hub and AWS Config will be upgraded to manage more complicated compliance needs. This will lower the risk of human errors and improve organizational efficiency in regulatory compliance.

3. Increased Emphasis on Hybrid Cloud Security

Implication: The coupling of on-premise systems with cloud-based SAP systems has been recognized as one of the greatest contributors to security threats. Since businesses will remain operating in hybrid cloud environments, the security of the hybrid systems will remain an ongoing issue.

Upcoming cloud infrastructures are expected to have improved hybrid cloud security platforms that ensure seamless cloud and on-premise resource integration. Next-generation cloud security products will enable persistent monitoring, policy management, and risk analysis, which will assure uniform security policies across environments.

4. Enhancing Cloud-Native Compliance Frameworks

Implication: With increasingly more industries and geographies adopting cloud technologies, organizations will need to contend with more regulatory complexity. The current compliance challenges with SAP implementations on AWS will drive the development of more cloud-native compliance frameworks tailored to specific industries.

Forecast: AWS and other cloud providers will expand their compliance certifications and frameworks to accommodate an increasingly long list of regulations so that businesses can stay compliant in a more efficient manner. Beyond that, specialty tools for certain industries like healthcare, finance, and retail will be tuned to provide more robust support for regulatory needs.

5. Accelerated Cloud Security Training and Certification Programs

Implication: The skills gap that has been identified in the study is going to continue to hinder the secure deployment and operation of SAP systems on AWS. To counteract this problem, there is going to be an increasing demand for training and certification programs in cloud security.

Projection: The cloud computing industry will witness an increased requirement for skilled individuals with SAP knowledge as well as AWS security setup expertise. Thus,

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ISSN(P) 2347-5404 ISSN(O)2320 771X

cloud computing service providers like AWS will likely invest in the creation of more comprehensive training and certification schemes, while businesses will focus more on hiring cloud security experts who are capable of managing complex cloud systems.

6. The Growing Importance of Zero Trust Architectures

Implication: As cloud environments become more complex and cyber-attacks more frequent, organizations will shift towards a zero-trust security paradigm, one that presumes that no device or user can be trusted automatically, even within the network perimeter.

Forecast: Zero-trust models will increasingly gain popularity when it comes to securing SAP on AWS. Under this system, organizations will have strict identification proof, ongoing surveillance, and least-privilege access protocols in place such that even users within the organization will be given limited access based on their respective roles.

7. Enhanced Incident Response and Threat Intelligence

Implication: As the complexity of SAP deployments in AWS increases, organizations will need to enhance their incident management and threat detection to manage existing security threats in an effective manner.

Forecast: The integration of threat intelligence systems and automated incident response in cloud environments is likely to grow exponentially. This will enable organizations to identify potential security threats at an earlier stage, automate the response, and contain risks in a timely fashion, minimizing the impact of potential breaches in SAP systems.

8. Growth in Multi-Cloud Deployments

Implication: The study highlighted the complexity involved in hybrid cloud architectures; however, the implementation of multi-cloud strategies, which involves the use of multiple cloud service providers, is expected to pose further complexities. The adoption of multi-cloud environments, where SAP systems are installed on different providers like AWS, Azure, and Google Cloud, is expected to grow.

Anticipation is that multi-cloud approaches will lead to a growth in the number of tools and platforms that are designed to provide integrated security, compliance, and governance across different cloud service providers. Organizations will increasingly employ multi-cloud management platforms in a bid to provide consistent security practices and regulatory compliance across their cloud environments, thereby making SAP systems stronger.

9. Security and Compliance Monitoring with AI Implication:

With growing sophistication in security threats and combined with a rapid increase in the amount of data generated within cloud environments, artificial intelligence and machine learning technology will converge and augment security monitoring and controls and compliance. Prediction: AI-based security solutions will be incorporated into AWS infrastructures to scan SAP deployments on a continuous basis for security risks and compliance issues. These solutions will be capable of processing enormous amounts of data, recognizing patterns, and anticipating vulnerabilities before they occur, allowing organizations to take pre-emptive measures.

10. Enhanced Security Features for SAP HANA in Cloud Environments Implication:

SAP HANA, which is commonly deployed on AWS, has unique security issues due to its performance-driven nature and the large volume of sensitive information it processes. Anticipated innovations in the integration of AWS and SAP are likely to revolve around extending security features for SAP HANA in the cloud. They are likely to include advanced encryption techniques, improved access control, and improved security tool integration in a bid to detect and shield SAP HANA deployments from emerging threats.

CONFLICT OF INTEREST

Conflict of interest, in the context of this research, shall mean any situation where the research process or the research findings would be influenced by personal, professional, or financial interests that would undermine the objectivity and integrity of the research. Disclosure of any conflict of interest is required to ensure openness and uphold the validity of the research findings.

This study examines the security and compliance implications that are involved in implementing SAP systems on Amazon Web Services (AWS) and has been conducted without any financial support, sponsorship, or external affiliations that may affect the findings or results. The authors attest that they have no competing financial interests, personal connections, or affiliations that could have affected the study design, conduct, or reporting.

Furthermore, the conclusions and recommendations given in this research are based solely on an objective analysis of the security and compliance issues that organizations deploy SAP on AWS. The study design, data collection methods, and analysis steps have been carried out in an impartial manner so that all the conclusions drawn are from the research findings and not influenced by external pressures or interests.

Vol. 08, Issue 09, September: 2020
ISSN(P) 2347-5404 ISSN(O)2320 771X

There must be a distinct line of demarcation between personal or professional interests and the research approach so that the findings of the study are valid, credible, and free from the undue influence of personal or professional interests. Through this, any further research on this topic will also be guided by ethical standards ensuring transparency and neutrality of the research.

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