

Future - Proofing SAP HANA with Hybrid Cloud Architecture: Achieving Agility, Compliance, and Cost Efficiency

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Abstract: *The hybrid cloud architecture for SAP HANA provides organizations with a solution for combining agility with compliance in a cost-efficient manner. With more businesses taking big steps to migrate to cloud environments, hyperscale cloud models allow running of critical SAP HANA workloads in private clouds and taking advantage of public clouds for scalability and cost effectiveness. This enables agility in rapid innovation, scaling resources on demand and to thrash to business changing demands. Also, in parallel, hybrid cloud solutions enable compliance with strict data security regulatory regimes as they provide data residency controls, encryption and secure data transfer based on customers' demand. They permit organizations to meet industry specific regulatory requirements whilst still retaining operational flexibility. Pay per use pricing models achieve cost efficiency by reducing the need for large investments for infrastructure, whilst resource optimization techniques, such as automated scaling and workload balancing, guarantee that businesses only pay for what they use. While hybrid cloud deployments are inherently complex, new technologies such as containerization, AI and automation are lowering the barriers to adoption and use of these environments.*

Keywords: hybrid cloud, SAP HANA, cloud scalability, data security, cost efficiency

1. Introduction

In today's digital environment businesses are under constant pressure to innovate, optimize, reduce costs and comply with strict regulatory and compliance rules. With in - memory computing capabilities of SAP HANA, it has become a major solution for the enterprises that require real time data processing and analytics for making decisions and increasing operational efficiency. But as data workloads and operational requirements grow, organizations are increasingly adopting

hybrid cloud architectures to exploit benefits of both on premises infrastructure as well as cloud environments. By providing businesses the agility to enable rapid scaling, flexible deployment and easy integration with other systems, and enabling compliance to regulations regarding industry specifics or data residency, a hybrid cloud approach allows an organization to achieve agility. This architectural model also offers an opportunity for cost efficiency by utilizing public cloud pay - as - you - go services for the non-mission critical workloads, while retaining sensitive or high-performance workloads on premises.

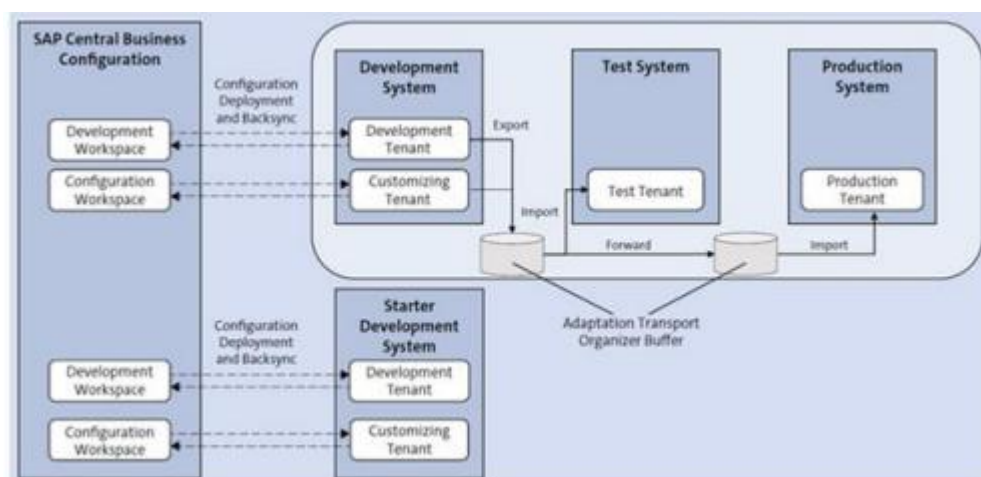


Figure 1: The SAP S/4HANA Cloud Three - System Landscape

Organizations are able to optimize costs, cut capital expenditures, and leverage the most resource utilization by combining private and public cloud resources. As you can imagine, deploying SAP HANA on a hybrid cloud platform

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comes with challenges. Achieving data synchronization, low latency, and security in the face of data redundancy and coordination across different environments that require orchestration is a challenge that businesses need to solve. The adoption process is further complicated with navigating through compliance frameworks across regions, industries, and jurisdictions. However, the hybrid cloud solutions designed for SAP HANA are also proving to be transformational, giving businesses the best of both worlds — operational flexibility, regulatory compliance and financial prudence.

2. Background of the Study

The evolution of technology at an extremely high pace is reshaping the way organizations handle, process, and utilize data for the competitive advantage. With SAP's advanced in-memory database and analytics platform, SAP HANA has emerged as an indispensable component in the armory of enterprises that need to work with loads of data in real time. Due to its capacity for high speed transaction processing and advanced analytics, the financial market deems it as a key enabler for digital transformation. Despite this, the traditional on-premise deployments of SAP HANA are often constrained by scalability, flexibility, and cost management issues compelling organizations to move to the cloud. Combining the strengths of private and public clouds, hybrid cloud architecture has begun to emerge as an attractive model to solve these challenges. With it, businesses can take some or all of the benefits of public cloud environments while maintaining control over sensitive data. With sectors such as finance, healthcare, and manufacturing requiring data always online and their data to be always compliant with strict regulatory frameworks, sometimes which can go as far as data sovereignty compliance, this balance becomes all the more important. The hybrid cloud robustly supports diverse workloads, optimizes resource utilization and adaptability to evolutionary changes of businesses in which differs it as a superior choice for deploying SAP HANA.

3. Importance of Balancing Agility, Compliance, and Cost Efficiency Study

The simple truth is that using technology to compete in this rapidly changing business world requires organizations to strike a fine balance of agility, compliance and cost efficiency. Hybrid cloud solutions are dynamic and scalable infrastructures, which agility allows any business to adapt

quickly to market changes, scale operations and innovate. However, this flexibility is critical when deploying enterprise application such as SAP HANA, which requires real time processing and can respond to fluctuating workloads. Agility cannot happen and shouldn't happen at the expense of compliance in certain sectors like finance, healthcare, and government where we have regulations around data privacy, data sovereignty, data security controls. In case these regulatory standards cannot be met, a company can be subject to severe financial penalties, damage to reputation of the company and disruption of operation. At the same time, organizations have to manage costs effectively so that technology investments provide that value in an optimal manner. Balancing these complicated needs is terribly difficult — but hybrid cloud architectures strike this balance by offering flexible workload placement, resource utilization optimization, and support for governance requirements. Using public cloud environments for the cost effective ability to scale non-sensitive work, but private clouds provide the control and ensure compliance. This equilibrium can be reached provided you devise robust planning, always monitor and make use of advanced automation and security tools. Inefficiencies, higher risks, and missed opportunities are the result of misalignment in any of these areas. As a result, agility, compliance, and cost efficiency balancing is not only a technical need but also a strategic pull that allows them to foster their growth, retain trust and secure a sustainable competitive advantage in an increasingly complex and challenging digital environment.

4. Hybrid Cloud Architecture for SAP HANA

SAP HANA hybrid cloud architecture is a combination of private and public cloud capabilities that deliver an integrated, scalable and secure infrastructure solution tailored to enterprise requirements. With this architecture, organizations can tap into SAP HANA's in-memory data processing capabilities while maintaining their ability to be agile, compliant, and cost efficient. Hybrid cloud consists of private clouds which run mission critical workloads, public clouds which offer scalable and flexible resources and orchestration tools that guarantee seamless integration and workload management. Secure gateways and virtual private networks (VPNs) are critical networking components that are used to connect disparate environments, while identity and access management systems protect access to sensitive data and applications.

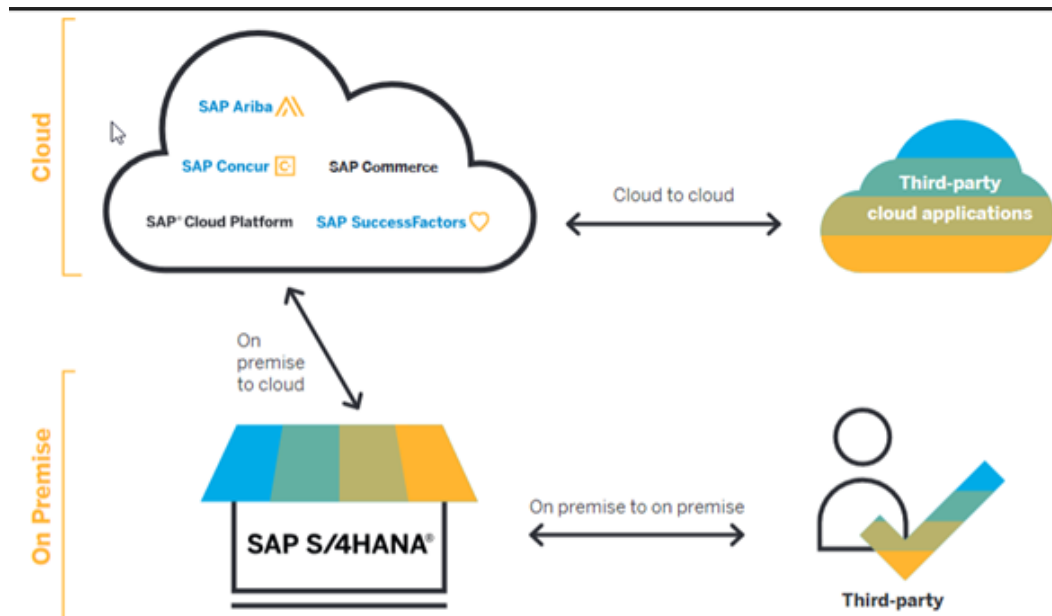


Figure 2: Cost Comparison between Cloud - Based and Traditional SAP Systems

Integrating SAP HANA into this hybrid model invariably implies deploying its high performance computing features such that data processing is achievable in the least effort across the systems. This could mean separating transactional and analytical workloads in which, for instance, time sensitive transactions reside on private clouds for speed and compliance, and analytical workloads are migrated out onto public clouds for scalability. Efficient deployment of hybrid cloud requires a series of thoughtful design considerations, including latency optimization, workload distribution and sound outage recovery mechanisms to support business continuity. SAP HANA goes a step further to deploy at the container level and microservices to increase the flexibility of its deployment with portable, lightweight application components. Containers guarantees consistency across environments. Microservices allow incremental updates and scale without disrupting current work flows. This architectural approach gives organizations control of sensitive data, allows for compliance with regulatory rules, and accommodates resource flexibility according to varying demand, while leveraging costs. Hybrid cloud architecture for SAP HANA is an adaptable and future ready solution for enterprise IT modernization, resulting through the integration of advanced technologies and best practices.

4.1 Advanced Data Management for Future - Ready SAP HANA Architectures

The increasing scale and complexity of enterprise data demand robust strategies to ensure performance, scalability, and operational efficiency in SAP HANA deployments. Advanced partitioning and data lifecycle optimization are crucial for managing large datasets, particularly in hybrid cloud environments.

SAP HANA's **partitioning techniques**, including range and hash partitioning, play a vital role in maintaining system efficiency. These methods ensure compliance with the 2 - billion - row limit per partition and improve query performance by enabling parallel processing and partition pruning. Effective use of these strategies significantly reduces

memory consumption and optimizes resource utilization, even under high - demand scenarios.

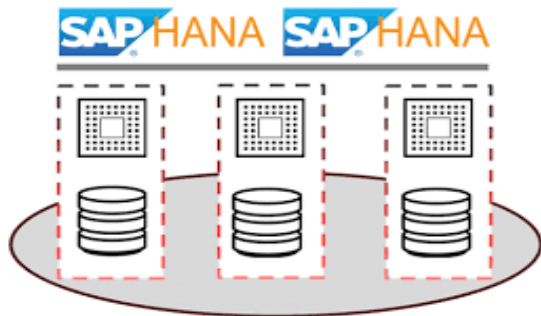
Additionally, SAP HANA's **Native Storage Extension (NSE)** empowers organizations to segregate "hot" and "warm" data effectively. Frequently accessed data remains in - memory, ensuring rapid processing, while less critical data resides on disk, reducing overall costs without compromising system responsiveness. This approach aligns perfectly with hybrid cloud environments, where scalability and cost management are top priorities.

Predictive scaling and **multi - cloud orchestration**, as highlighted in IJCC's study, further enhance agility in hybrid deployments. These techniques dynamically allocate resources based on workload demands, ensuring efficient operation during peak loads while minimizing infrastructure overhead. By integrating these strategies, businesses can ensure SAP HANA remains future - ready, capable of meeting the evolving needs of a data - driven enterprise landscape.

5. Balancing Agility in Hybrid Cloud for SAP HANA

To provide enterprises the ability to quickly respond to fluctuating business needs, while maintaining high performance and operational efficiency, we must find a balance of agility in the hybrid cloud environment for SAP HANA. In this context, agility means moving SAP HANA workloads with simplicity, flexibility, and freedom, across hybrid infrastructures. Achieving this balance is central to achievement of which agile deployment strategies facilitate the speedy time to market of new and updated applications. Organizations can incrementally roll out new features without disruptions by adopting modular and flexible deployment approaches. These strategies comprise the use of pre configured SAP HANA templates, containerized deployments, and microservices to lead to portability and reduced complexity of deployment. Agility also has the cornerstones of real - time scalability, where it is possible to change dynamically the resources used based on the demand

of the workload. Businesses can scale vertically within private clouds for performance sensitive workloads or scale horizontally across public clouds for fluctuating or seasonal demands, all with hybrid cloud architecture. Load balancers and in memory caching are just a couple of the performance optimization tools that provide SAP HANA the surprising ability to perform even under peak circumstances, while still offering great response times. Automation tools and CI/CD pipelines also aid agility by automating the development, giving greater speed and modern approaches to testing and deployment.



Automating routine tasks and introducing continuous integration and continuous delivery (CI/CD) workflows help the business facilitate rapid, error free updates across their SAP HANA systems. Consistent deployments across hybrid environments are supported by these pipelines that reduce manual intervention and improve reliability. These strategies work together to enable organizations access to a flexible hybrid cloud infrastructure while following the speed of a competitive and fastpace digital environment.

6. Ensuring Compliance in Hybrid Cloud Environments

Deploying enterprise critical database SAP HANA in a flexible and secure architecture but transforming its compliance needs in hybrid cloud environment is a must. For industries such as finance, healthcare, and government, where data privacy is of the highest importance, data integrity, and accountability, hybrid cloud deployments must comply with many specific regulatory and security requirements. By nature and because of regulatory standards such as GDPR, HIPAA, and SOC 2, stringent measures for handling, encrypting, and accessing data are a requirement which must be smoothly incorporated with the hybrid cloud infrastructure. And then they also introduce another layer of complexity with data residency and sovereignty challenges that are applicable to organizations that span multiple jurisdictions with conflicting laws regarding where data can be stored or transferred. This requires that sensitive or regulated data is contained within private clouds or on private systems as necessary by local law (in a hybrid scenario) and still utilizing public cloud for scalable workloads. In order to resolve these issues, various organizations will need to formulate and apply effective compliance management strategies which will span across detailed mapping of regulatory requirements, automated compliance monitoring and making use of hybrid cloud native tools aimed at achieving persistent policy enforcement. In order to mitigate risks and protect sensitive data; security measures must include end to end encryption and advanced

threat detection as well as multi factor authentication. Further, techniques for avoiding risk include regular security audits, disaster recovery planning, and failover systems to assure operational continuity and avoid breaches or data loss. Businesses can successfully use hybrid cloud architectures for SAP HANA by aligning technology, processes, and governance, so as to comply with the regulation, protect the data and minimize exposure to regulatory penalties.

7. Literature Review

Halmela, T. (2017). Through the SAP Hybris Service Engagement Center, it also demonstrates how cloud product innovations can speed up the move to sales by enabling sales operations to become an integral part of customer service. The Service Engagement Center is a cloud native solution within the SAP Customer Experience suite which marries service and sales processes, empowering the business to deliver contextually relevant customer interactions and to act in real time on sales opportunities. This platform is an innovative one which uses advanced analytics, AI based recommendations, and omnichannel communications to help you improve customer engagement and increase conversion rates. The system, by giving customer service agents a 360 degree view of the customer, including purchase history, preferences and previous interactions with the company, makes for more informed and effective interactions with the customer. Upon a contact of the service team by customers to find guidance, the platform exploits predictive analytics and machine learning for the spotting of upselling or cross selling opportunities based on customer needs.

Polukhov, T. (2023). Organizations looking to thrive and prosper within a competitive space, must transform their business processes. Five key paths drive this transformation: Such features are: automation, digitization, data driven decision making, collaboration and agility. Automation repeats tireless tasks, diminishes errors and frees up resources for predominant tasks, while digitization cuts down manual tasks with advanced digital tools and platforms. Organizations relying on data driven decision making are empowered with analytics and real time insights — enabling them to make informed decisions, improve efficiency and become more innovative. Collaboration helps teams work in tandem, department's partner, and external partners synergize to break those silos and combine their efforts towards shared initiatives.

Tejada, A., et al (2022). Business performance is being optimized through cloud solutions that optimize product delivery processes in a way of augmented efficiency, scalability, and real time insights. Using cloud based platforms, businesses can streamline their supply chain operations, automate order processing as well as inventory management to make sure that products reach customers on time and are accurate. Such solutions give real time visibility into logistics and enable pro action by taking corrective decisions and reducing delays arising out of disruptions. The integration of the advanced analytics tools enable businesses to predict demand, optimize routes, distribute resources efficiently to minimize the cost and boost customer satisfaction. Fluctuating demands for services can be supported by cloud systems, for which performance is

maintained consistently during peak periods without over burdening infrastructure.

Kulkarni, S. (2019). In order to plan and execute the journey to SAP S/4HANA, in a structured way, in the most seamless manner and to minimize risks and maximize value, there is a need for a program framework. The project starts with an assessment phase involving detailed assessment of business objectives, system requirements and existing IT landscape. Afterwards, comes the strategy phase where the organizations need to select the deployment model—on premises, cloud or hybrid—and choose from greenfield (brand new), brownfield (migrated or upgraded) or selective migration approach. In the project planning phase we need to define milestones, timelines and resources allocation with stakeholders' alignment. In the execution phase, it includes data migration, integration of SAP S/4HANA with existing systems and rigorous testing to ensure that all functionality and performance is aligned.

HANA, D. R. S. (2013). To build a trusted SAP HANA data center, we need a solid foundation of security, performance and compliance to fulfill the demands of mission critical business operations. Hence, the data center must also be designed to be highly available with redundant systems and disaster recovery plans minimizing the downtime. Sensitive business data is secured from cyber threats through advanced security measures, such as encryption of data at rest and in transit, multi factor authentication, and secure access controls. To satisfy regulatory necessities and instil client trust, an organization should conform to industry principles, similar to ISO 27001, SOC 2 and GDPR. Another crucial criterion is scalability; i. e. it must be able to grow with growing workloads and managed changes to meet the business need. Intelligent monitoring tools and proactive maintenance are key to spot impending failures and ensure performance, eliminate unexpected downtime, and as a result, your business can go on rails.

8. Achieving Cost Efficiency

Enterprises striving to optimize return on investment with operational excellence look upon the ability to achieve cost efficiency in hybrid SAP HANA deployments as a strategic imperative. Flexible cost models offered by hybrid cloud architectures are applicable to a wide arena of business needs. The public cloud offers pay - as - you - go and subscription based pricing models for the resources to prevent large initial investments in the infrastructure required with on premises deployments. However, mission critical workloads are often carried out on mission private clouds or on prem systems where predictable and consistent performance is key. Optimizing spend between hybrid environment allows organizations to balance these cost models. Additionally, cost efficiency is further improved with resource optimization strategies whereby computing, storage and networking

resources are applied effectively. Workload right - sizing, de - duplication of data, and automated scaling techniques minimize waste and lower expenses. Organizations can dynamically reallocate resources to where they're needed most by employing tools for resource monitoring and predictive analytics in order to prevent overprovisioning, and to preempt underutilization. Total Cost of Ownership (TCO) calculations for SAP HANA in a hybrid cloud setup is also required to be analyzed in order to anticipate the full financial impact over the long run. That means more than just the cost of hardware, software, and the cloud but also maintenance, training and compliance too. TCO analysis is used to find areas of efficiency loss and to make informed decision of workload placement and technology investment. Following these strategies, enterprises can get a cost effective hybrid cloud deployment of SAP HANA with an optimal combination of economic and operational performance.

9. Advanced Hybrid Cloud Features for SAP HANA

With advanced hybrid cloud features organisations are revolutionizing with the deployment and optimisation of SAP HANA, unlocking greater efficiency, intelligence and adaptability. SAP HANA's performance and operational efficiency within hybrid cloud environments is dramatically transformed by Artificial Intelligence (AI), and Machine Learning (ML). With the help of AI powered analytics, predictive maintenance, workload forecasting, real time anomaly detection can be done, in order to prevent problems and optimize resources dynamically. With machine learning models embedded in SAP HANA, data driven insights are enabled with predictive analytics, automated decision making, and more, specific to a company's needs. With these kinds of capabilities, organizations can get the most value from their data, and be most agile in their hybrid infrastructures. Edge computing, when integrated with hybrid cloud environments, is an extension of SAP HANA whose additional functionality can readily be used by industries that emphasize real time data processing near the source location. Businesses can reduce latency and increase speed by processing data locally at the edge because some applications like IoT applications, manufacturing automation, or even the remote site management are dependent on continuous operations. This also minimizes the transfer of data to the central cloud making it a cost efficient solution. Hybrid cloud architectures for SAP HANA heavily rely on advanced networking solutions such as software defined networking (SDN) and high speed interconnects to guarantee a fluid communication and data flow between private and public cloud elements. Low - latency, high bandwidth connections from our datacenters to your cloud via Direct Connect or Express Route optimize performance for your mission critical workloads.

10. Results

Table 1: Comparison of Hybrid Cloud Deployment Models for SAP HANA

Deployment Model	Description	Benefits	Challenges
Private Cloud (On - Premises)	Dedicated infrastructure managed by the organization or a trusted provider.	Full control over security and compliance.	High capital investment, scalability limitations.
Public Cloud	SAP HANA hosted on cloud platforms like AWS, Azure, or Google Cloud.	Scalable, flexible, pay - as - you - go pricing model.	Potential security and compliance concerns.
Hybrid Cloud	Combines private and public cloud environments, with workloads distributed between the two.	Optimized for cost, performance, and flexibility.	Complex integration, requires robust governance.
Multi - Cloud	Use of multiple public cloud services to avoid vendor lock - in.	Improved flexibility, reduced risk of dependency on a single cloud provider.	Increased complexity in managing multiple cloud environments.

Table 2: Compliance and Security Considerations in Hybrid Cloud for SAP HANA

Compliance Factor	Description	Implementation Strategy	Challenges
Data Residency	Ensuring data is stored in specific regions to meet legal and regulatory requirements.	Leverage hybrid cloud flexibility for regional data placement.	Complex governance across multiple regions.
Encryption	Protecting data at rest and in transit to prevent unauthorized access.	Use advanced encryption protocols like AES - 256, SSL/TLS.	Key management and encryption overhead.
Regulatory Compliance	Adherence to industry regulations (e. g., GDPR, HIPAA, PCI DSS).	Implement automated compliance reporting and audits.	Balancing compliance requirements across clouds.
Identity and Access Management (IAM)	Managing access to sensitive SAP HANA data to prevent unauthorized usage.	Integrate IAM with single sign - on (SSO) and multi - factor authentication.	Maintaining consistency in access policies.

Table 3: Cost Implications of Cloud - Based vs. Traditional SAP System

Cost Category	Cloud - Based SAP System	Traditional SAP System
Initial Setup Costs	Typically lower due to no need for on - premise hardware	High setup costs for purchasing hardware and infrastructure
Infrastructure Costs	Ongoing subscription - based pricing (e. g., per user, per usage)	High upfront cost for servers, data centers, and storage
Software Licensing	Subscription model (monthly/annual)	License fee for software and additional modules (upfront)
Maintenance & Support	Managed by the cloud service provider, included in the subscription	Requires in - house IT teams or third - party support contracts
Customization Costs	Pay - per - use model for additional features or customization	High costs for custom development and integration
Scalability	Easily scalable based on demand (pay - as - you - grow)	Scalability requires additional hardware and resources
Hardware/IT Staffing Costs	None, as hardware is managed by the cloud provider	Significant cost for hardware, data centers, and IT staff
Energy/Utility Costs	Minimal (cloud provider manages power consumption)	High utility costs for on - premise servers and data centers
Upgrades & Patches	Included in subscription (frequent, automatic updates)	Requires manual upgrades and patches, which can be costly
Disaster Recovery & Backup	Built - in disaster recovery and backup services (included)	Requires separate backup solutions and disaster recovery systems
Total Cost of Ownership (TCO)	Generally lower overall due to reduced hardware and operational costs	Higher due to infrastructure, maintenance, and support costs

11. Migration Strategies to Hybrid Cloud for SAP HANA

Migrating SAP HANA to a hybrid cloud deployment is a complex but rewarding endeavour and involves deep planning, right execution, and the right tools and technologies to successfully achieve the desired results. First is the thorough assessment of the existing SAP HANA deployment, from looking at existing infrastructure, applications that depend on it, performance metrics and the amount of data that would be placed on it. This step is important to determine whether the workloads have the most appropriate energy to migrate to the public cloud rather than an on - premise or an in a private cloud environment, by the sensitivity requirements, compliance requirements and final result requirement. The transition is guided once the assessment is

done to migration pathways and best practices. That usually means a lift and shift, re platforming, or re architecting approach based on the complexity of the SAP HANA environment and goals. For instance, we frequently need to re - architect mission critical workloads to achieve optimal performance and compliance in a hybrid set up. Achieving seamless migration depends heavily on tools and technologies. The process of migration can be simplified with the help of cloud migration platforms, data replication tools, and orchestration solutions that automate activities like workload replication, data synchronization or system integration. Multiple tools from cloud providers and other third party vendors enable them to provide solutions that ensure consistency, reliability, and limited downtime while bringing their processes to the cloud. An essential part of the strategy is how to overcome migration bottlenecks like data transfer latency, compatibility issues and system downtime

amongst others. Phased migration and pilot testing, along with taking advantage of hybrid connectivity options (Direct Connect or ExpressRoute) can help mitigate risk and expedite the procedure. Migrations can be very robust in the data using backup and recovery plans. With a thorough assessment, strategic planning, built in tools, and diligent management of bottlenecks, organizations can safely onboard SAP HANA into a hybrid cloud environment retaining the benefits of agility, scalability, and cost efficiency without sacrificing operational continuity or compliance.

12. Scope of the Study

This thesis addresses implementation and optimization of hybrid cloud architecture for SAP HANA with the aim of addressing balance between agility, compliance and cost. It discusses how hybrid cloud solutions can meet the increasingly high levels of processing, analytics, and decision making associated with the modern enterprise and particularly those enterprises built around SAP HANA for real-time data processing. This scope includes the hybrid cloud environment design principles and the strategies that include integration strategies where private and public cloud resources integrate into a single and scalable infrastructure. Finally, the study studies which of these critical factors of agility—specifically, dynamic workload management, scalability, and seamless system integration—are affected and the associated compliance challenges on account of varied regulatory frameworks and data sovereignty laws. The book explores the means by which robust data security, governance, and compliance with industry specific regulations can be enforced without undermining operational flexibility.

13. Conclusion

Hybrid cloud architecture for SAP HANA is a transformative strategy that enables businesses to find an optimal balance between agility, compliance, cost and supporting today's business requirements. Hybrid cloud models offer a well suited platform for SAP HANA deployments by maintaining the scalability and flexibility of public cloud resources, with the control and security of private cloud premises. Dynamic resource allocation, real time data processing and handling, and a seamless integration across environments provide our business with agility in adapting to the incessant market needs. Robust governance frameworks, encryption, and secure data transfers tackle compliance challenges like data residency and stringent regulatory requirements to ensure data security. The hybrid cloud solutions yield cost efficiency with capabilities to pay as you go, minimize infrastructure overheads and optimize the value of resources available. By enabling businesses to strategically position workloads—critical operations onto private clouds and elastic analytics onto public clouds—without sacrificing compliance or Upping budgets, businesses can optimize performance. For all the difficulties presented by hybrid cloud deployment, technologies like automation, AI, and containerization have made the task easier and easier, making hybrid clouds evermore an approach that enterprises can adapt. With hybrid cloud architecture for SAP HANA, organizations migrate to a future ready foundation to support growth, increase operational efficiency and achieve sustainable business value – on a secure, flexible and standardized cloud platform. Going

forward, this approach solves current challenges and sets businesses up as beneficiaries in a quickly changing digital landscape.

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