**A study on Database Options in the Cloud**

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**ABSTRACT**

Today's organizations need a lot of information and data to succeed, therefore keeping that data and information is a huge difficulty. Typically, databases are used to store all data and information, but once again, their storage capacity is constrained. A cloud database can help with this. A cloud database is one that is developed, managed, kept, and used in a cloud setting. These databases offer capabilities akin to conventional databases and may be accessed via a web interface. For most companies, managing their own databases can be quite a costly affair and therefore these companies look for alternatives that can ease out the process of managing and storing data. Cloud databases offer several benefits to users. Databases are essential to today's technological world, providing effective ways to store and access data when needed. With the growth of cloud computing, many organizations have shifted to using a cloud database—a form of distributed storage where your data is replicated across multiple independent systems in the same network.This article focuses on cloud databases with their types, advantages, considerations when choosing cloud database, and popular cloud database services .

1. **INTRODUCTION**

By 2028, the cloud databases and DBaaS market is projected to be worth USD 57.5 billion, up from USD 21.3 billion in 2023 at a Compound Annual Growth Rate (CAGR) of 22%[1]. The expanding need for social media, digitalization, and ongoing innovation are the major factors propelling the expansion of the cloud database and DBaaS sector. The surge in the number of medium-sized and small businesses using Cloud Databases and DBaaS,with limited resources available to optimize their operations, has significantly promoted the market's user base expansion.

A cloud database, commonly referred to as DBaaS, is a database-as-a-service that is offered on a cloud computing platform. Renting databases from cloud database service providers with vast storage capacity enables efficient administration of massive amounts of data. Additionally, by providing access to cloud database systems, these services spare organizations the time necessary for setting up the necessary hardware, software, and configurations. Cost effectiveness and effective time management of cloud databases and DBaaS services are further advantages.

1. **What is cloud database?**

A database service that is built and accessible using a cloud platform is known as a cloud database. Many of the same purposes of a conventional database are still served with cloud database, but with the extra flexibility of cloud computing. A cloud database is deployed, delivered, and accessed in the cloud[2][3][4].

Cloud databases manage and store structured, unstructured, and semi-structured data like conventional on-premises databases. But Cloud databases also provide many of the same advantages of cloud computing, such as speed, scalability, agility, and lower prices.

1. **Models for cloud database**

There are two deployment models for cloud databases, Cloud databases can be offered as a managed Database-as-a-Service (DBaaS) or deployed on a cloud-based virtual machine (VM) and self-managed by an in-house IT team[5][8].

### Traditional database or Self-managed databases

This is fairly the same as a locally managed database—except for infrastructure provisioning. In this, the database is deployed to the cloud after a business acquires virtual machine space from a cloud services provider. The database is managed by the company's developers, either through a DevOps model or by traditional IT personnel. The organization will be responsible for supervision and database administration.

### DBaaS stands for Database-as-a-service.

In which an organization do agreements with a cloud provider by paying the subscription fee. The cloud service provider provides the end user with a range of real-time operational, maintenance, administrative, and database management tasks. This database is running on the infrastructure of the service provider. The vendor provides not only hardware

but also the server software itself. Most vendors offer both traditional databases (such as Oracle and MySQL) and cloud native databases that are specific to that vendor.

 In this model, automation is usually in the area of provisioning, redundancy, scaling, high availability, security, patching and health monitoring. The DBaaS model enables organizations to benefit from the outsourcing of database management that is optimized by software automation, and not be required to recruit or manage experts in their own databases.

Managed databases significantly alter the way you work; self-managed databases are far more like running your own database on-premises.

**The main variations are as follows[8]:**

* + If you use a managed database, you will not have to download, install, update, set up, or back up the database yourself—the cloud provider will take care of everything. You can still change parameters that tell the database how to run (collation, cursors, connections, etc.). You can also manage choices like whether to install new releases and how long to retain backups.
	+ Occasionally, the cloud vendor can provide a license for a proprietary database and include the cost with the cost of using the cloud service. In other situations, getting a license is still your responsibility. If you already bought a license from a proprietary database vendor, you are sometimes able to use that to a managed database.
	+ You are only given the options the vendor makes because they install and administer the managed database. You cannot request a database engine or even a version that the vendor does not already provide. However, the three major providers (AWS, Azure, and Google) provide both their own cloud-native databases as well as a number of proprietary and open-source databases.
	+ Self-managed and managed databases have different configuration options.
	+ With managed databases, the vendor often handles security. But even a managed database leaves key security decisions up to you, such who to provide accounts to and what restrictions to put on tables or columns. Normally, it is still your responsibility to keep an eye on and audit access attempts. Security options such as which IP addresses have access are also within your control.

Managed databases therefore offer many advantages over on premises deployments and self-managed databases, but you might have unique reasons to run your own database.

**Cloud Native Databases**

Managed databases can be split into two groups: traditional and cloud native[8]. Traditional databases like Oracle, SQL Server, MySQL, and PostgreSQL are routinely provided by cloud service providers as managed databases. If one of these databases served as the foundation for your company's on-premises design, switching to the same database in the cloud makes the migration process easier. You will not likely need to change your applications, and you can manage the databases with similar tools. You can also mix offerings from different vendors or maintain your on-premises version of the database.

However, the cloud service providers have put a lot of work into developing new products of their own, which are frequently referred to as cloud native databases. Vendors provide evidence that the cloud native databases perform better, scale more easily, and are cheaper in the long run. Thus, testimonials from Autodesk and InfoScout suggest that AWS engineers have solved many of the scaling and efficiency problems of managing relational databases in the cloud with their own database, Amazon Aurora. Cloud

 native databases are also designed to scale enormously, a task that has historically been difficult for relational databases.

1. **Types of Managed Databases**

Most database types you will come across in the industry are also available as managed databases. Furthermore, cloud providers have developed their own cloud-native databases that provide performance benefits as well also following common industry trends. The examples of the database types that are majorly supported include [8]:

1. **Relational databases**

Some cloud databases are managed versions of popular databases in widespread use. For example, Azure offers Microsoft's traditional SQL Server. Amazon supports MariaDB, MySQL, Oracle, PostgreSQL, and SQL Server through Amazon Relational Database Service (RDS). These offerings help you migrate databases from on-premise installations more easily. In addition, cloud providers have created their own databases. For example, Azure offers Azure Cosmos DB, Google Cloud provide Cloud Spanner and Amazon Aurora is provided by AWS.

1. **Data warehouses**

These are usually relational databases, but they differ from transaction-oriented databases internally and in the offerings they offer. For example, a transaction-oriented database typically stores all the columns in a single row, so you can quickly retrieve multiple columns for a customer or a product.

Data warehouses, on the other hand, are columnar databases in the cloud. This means that data is stored by the column, rather than by the row. This greatly accelerates common warehouse queries, such as "give me the ages of all customers living in California. “The tools that cloud companies offer with data warehouses are geared at quick ingestion and extraction, making them simpler to utilize in big data applications. These solutions, for instance, include Azure's SQL Data Warehouse, Google's BigQuery, and Amazon Redshift.

1. **Nonrelational databases**

This term is commonly used to cover a variety of different data stores that, unlike traditional relational databases, are built for special-application use cases. Cloud vendors offer a variety of these for different purposes:

* Key/value databases enable fast value storing and retrieval without support for more sophisticated activities.
* Document databases store data as JSON documents with a flexible schema, allowing data to be stored and queried in the same format used in applications
* In graph databases, relationships among the objects are stored, which makes it simple to execute algorithms like identifying the object with the most connections.
* Search databases optimize the location of documents containing particular words
* Time series databases record events with timestamps and are optimized for time-related tasks such as graphing occurrences of events over time, useful for tracking events such as device readings or web postings.
* Ledger databases are like enhanced, secure log files that record activities such as financial transactions, signing them, and making them immutable.
1. **Important characteristics of cloud databases**

**The key features of cloud databases are[3]:**

* A database service is built and used using a cloud computing platform
* Enables enterprise users to host databases without buying dedicated hardware
* They can be managed by the user or offered as a service and managed by a provider
* They can support relational databases like MySQL and PostgreSQL as well as NoSQL databases like MongoDB and Apache CouchDB.
* Can be accessed via a vendor-provided API or web interface.

## **Advantages of cloud databases**

Cloud databases offer following benefits[4][6]:

1. **Reduces operational overhead**

The maintenance and management of any physically situated infrastructure will be eliminated by cloud databases. Provisioning, updating, and maintaining any hardware, operating system or database software shall be the responsibility of your cloud provider.

1. **Improved agility and scalability**

A new cloud database may be launched or released in minutes. You can test, operationalize, and validate new concepts more quickly as a result. Additionally, cloud databases can offer constant performance under heavy load and dynamically scale as your applications grow.

1. **Lower total cost of ownership**

Because the cloud service provider owns and manages the infrastructure, teams can concentrate on developing applications. Pay-as-you-go alternatives also enable you to furnish what you require ,when you require it and scale up or down in accordance with your use.

1. **Flexible database options**

You may select specifically designed cloud databases with the features and performance that meet your unique use case and application requirements.

1. **Safe, secure data**

To provide several levels of security and experts that can assist in securing client data without impeding innovation, cloud providers invest in the latest technology and specialists.

1. **Better reliability**

There are a number of built in features on cloud platforms, including cloud databases that aim to ensure continuous connectivity and compliance with the Service Level Agreements, such as high availability, automatic Backups or robust Disaster Recovery.

1. **Security for Data and Applications in the Cloud**

Introductions to cloud computing often organize the functions of an administrator on a stack, with the installation of physical servers and cabling at the bottom of the stack and application management at the top[8].

With managed databases, the majority of these duties are delegated to the cloud provider, leaving just application-level responsibilities the client's, hands. Self-managed databases retain the majority tasks in the client's hands, mostly leaving the vendor to supply basic networking and physical servers

With self-managed databases, the vendor's main responsibilities are to offer physical servers and the most fundamental networking.

The notion of a stack is also applicable to security duties, creating what is often known as a shared security model. In managed databases as opposed to self-managed databases, the vendor handles additional security-related activities.

In a nutshell, the cloud provider is in charge of infrastructure security, but you are still in charge of the security of your data and user information in cloud.

**Consequently, the following are some of the responsibilities handled by the cloud vendor:**

* providing network and application firewalls;
* providing identity management services that you configure;
* ensuring redundancy through replication and backups;
* patching and updating the software, including the database itself if you choose a managed database;
* running tools that monitor and audit access;
* providing network and application firewalls;
* protecting against DoS attacks; and
* physically securing the datacenter and equipment ,including the management of staff.

**The security tasks that the client is responsible are:**

* Using vendor’s Identity and Access Management(IAM) system ,set up users and the roles
* Allocate the users of database the access permissions. This can include creating accounts and roles, deleting users when access is no longer required i.e keeping the account up to date
* Set up alerts, review logs in order to detect unauthorized access
* If you are using your own Virtual Machine instead of managed database ,then secure the operating system
* Application-level security to prevent SQL injection attack
* Encryption of data which is at rest and in transit
* Access to databases or applications must first pass proper authentication and authorization
* Gathering and inspecting the logs
1. **Cloud Databases services from popular CSPs**
2. **AWS**

AWS provides a wide range of fully managed, purpose-built, and both relational and non-relational database services specially designed to handle any kind of application requirements. From fully managed database services, and a data warehouse for analytics, to an in-memory data store for caching, AWS has got it all [11].

You will find an AWS Database Service for just about any kind of database requirement. One can import an existing MySQL, Oracle, or Microsoft SQL database into Amazon’s databases or even build their own relational or NoSQL databases from scratch.

The following are different types of database services provided by AWS:

1. **Relational Database:**

In relational databases, the data is usually stored in a tabular format. Relational databases particularly use structured query language (SQL) to run queries to perform operations such as insertion, updating, deletion, and more. AWS provides the various relational database services. Some are listed below: -

* **Amazon RDS:** One of the most used database services provided by AWS that falls under the category of relational databases is Amazon RDS. Amazon RDS is a service that supports various open-source relational database products including the database products provided by AWS itself. RDS is used to set up, operate, and scale a relational database in the cloud.
* **Amazon Redshift**

Amazon Redshift is a fast and fully managed data warehouse service in the cloud. Amazon affirms that the Redshift data warehouse delivers ten times faster performance than other data warehouses utilizing Machine Learning techniques. The Redshift data warehouse can be scaled up to a petabyte or more as per the requirements.

* **Amazon Aurora**

Amazon Aurora is fully managed by Amazon RDS. It is a relational database engine built for the cloud. Amazon Aurora is also completely compatible with MySQL. Since Amazon Aurora is fully managed by RDS, all administrative tasks such as database setup, patching, backups, and more are automated.

1. **Key–Value Database:**

The key–value database is a type of NoSQL database where the method of having a value attached to a key is used to store data. Meaning that the data is composed of two elements, keys and values.

* **Amazon DynamoDB**

Amazon DynamoDB is a fast, fully managed, and flexible NoSQL database. It also supports document-based data. AWS affirms that DynamoDB delivers single-digit millisecond performance at any scale. DynamoDB comes with built-in Security, Backup, and Restore features. Since DynamoDB is a NoSQL database, it doesn’t require any schema.

1. **In-memory Database:**

This type of database is primarily based on the main memory for computer data storage. Basically, an in-memory database keeps the whole data in the RAM. Meaning that each time you access the data, you only access the main memory and not any disk. And the reason that the main memory is faster than any disk is why in-memory databases are so popular.

* **Amazon ElastiCache**

Amazon ElastiCache is a fully managed caching service that offers high-performance, cost-effective, and scalable caching solutions. Amazon ElastiCache provides two caching engines, namely, Memcached and Redis.

1. **Google Cloud**

Google Cloud databases provide you the best options in industry-leading reliability, global scale, and open standards for building data-driven applications [4][10].

1. **Database Type:Realtional**

**[Cloud SQL](https://cloud.google.com/sql)**

* Fully managed [MySQL](https://cloud.google.com/sql/mysql), [PostgreSQL](https://cloud.google.com/sql/postgresql), and [SQL Server](https://cloud.google.com/sql/sqlserver).
* Simplify migrations to Cloud SQL from MySQL, PostgreSQL, SQL Server, and Oracle databases with [Database Migration Service](https://cloud.google.com/database-migration).
* Set up easy-to-use, low-latency database replication with [Datastream](https://cloud.google.com/datastream).

**[Cloud Spanner](https://cloud.google.com/spanner)**

* Cloud-native with unlimited scale, global consistency, and up to 99.999% availability.
* Processes more than 2 billion requests per second at peak.
* Create a 90-day [Spanner free trial instance](https://console.cloud.google.com/freetrial?redirectPath=/spanner) with 10 GB of storage at no cost.

**[AlloyDB for PostgreSQL](https://cloud.google.com/alloydb)**

* Fully managed, PostgreSQL-compatible database service offering superior performance, availability, and scale for your most demanding enterprise workloads.
* Migrate from PostgreSQL to AlloyDB with [Database Migration Service](https://cloud.google.com/database-migration).
* [AlloyDB Omni](https://cloud.google.com/alloydb/omni) is a downloadable edition designed to run anywhere - in your datacenter, your laptop, and in any cloud.

**Bare Metal Solution for Oracle**

* Lift and shift Oracle workloads to Google Cloud.

[**BigQuery**](https://cloud.google.com/bigquery)

* Serverless, highly scalable, and cost-effective multicloud data warehouse designed for business agility and offers up to 99.99% availability.
* Enable near real-time insights on operational data with [Datastream for BigQuery](http://cloud.google.com/datastream-for-bigquery).
1. **Database type : Key-value**

**[Cloud Bigtable](https://cloud.google.com/bigtable)**

* Highly performant, fully managed NoSQL database service for large analytical and operational workloads. Offers up to 99.999% availability.
* Processes more than 5 billion requests per second at peak, and with more than 10 Exabytes of data under management.

##### **Database type: Document**

 **[Firestore](https://cloud.google.com/firestore)**

* Highly-scalable, massively popular document database service for mobile, web, and server development that offers richer, faster queries and high availability up to 99.999%.
* Has a thriving developer community of more than 250,000 monthly active developers.
1. **Azure Database Services**

When selecting a database in Azure, it helps to know exactly what features and compatibility you’re getting with each service. Below is a more detailed look at some of the most common services[12][13].

**Azure Cosmos DB**

Azure Cosmos DB is a fully managed, multi-modal database service. It offers turnkey, global distribution, multi-master replication, automatic scaling, and single-digit millisecond read/write latency. You can use Cosmos DB with SQL, Cassandra, MongoDB, Table, etc., and Gremlin through integrated APIs. With Cosmos DB, you also have the choice of selecting from five levels of consistency, from eventual to strong.

**Azure SQL Database**

[Azure SQL Database](https://bluexp.netapp.com/blog/azure-cvo-blg-azure-sql-database-18-options-for-sql-server-on-the-cloud) is a managed database service that you can use in Azure or on-premises via Azure Arc. It includes features for machine learning, scalability, data discovery, built-in security, and easy migration. You can use SQL Database as a Single Database for simple applications or Elastic Pool for multi-tenant applications.

**Azure Database for MySQL**

Azure Database for MySQL is a fully managed database service based on the community edition of MySQL. It includes all of the features that come with MySQL Community edition. It also includes built-in security, Advanced Threat Protection, and the ability to scale compute and storage resources independently. You can integrate this service with Azure Web Apps, WordPress, and Drupal.

**Azure Database for PostgreSQL**

Azure Database for PostgreSQL is a fully managed database service that you can use in Azure or on-premises through Azure Arc. It includes features for intelligent performance analyses, built-in security, and horizontal scaling through Hyperscale. You can integrate it with a wide variety of tools and extensions, including PostGIS, Timescale, and Visual Studio Code. You can also use it with a variety of frameworks and languages, including Python, Java, Ruby on Rails, Node.js and PHP.

**Azure Database for MariaDB**

Azure Database for MariaDB is a fully managed database based on the community edition of MariaDB. It includes features for high-availability, scalability, and built-in security. You can integrate it with Azure Web Apps, WordPress, and Drupal.

**Azure Cache for Redis**

Azure Cache for Redis is a fully managed, in-memory database service. It provides single-digit millisecond latency, flexible scaling, and built-in security. With Cache for Redis, you can replicate data across regions for greater reliability. You can also use caches in an Azure Virtual Network (VNet) for greater access control and security.

**What is Azure Database Migration Service?**

Azure Database Migration Service (DMS) is a fully managed service you can use to migrate data from databases and data warehouses. With it, you can perform either online or offline migrations. Online migrations allow you to continuously sync your data for minimal downtime. You can use DMS to move data from a variety of sources, including SQL Server, [Azure Oracle](https://bluexp.netapp.com/blog/azure-cvo-blg-azure-oracle-your-first-oracle-database-on-azure), MongoDB, and Cassandra.

When you use Azure Database Migration Service, the tool first helps you assess your current database assets, assesses your workloads, and provides recommendations for adjustments prior to migration. Part of this is accomplished through integration with the Data Migration Assistant, which can generate reports on your data.

1. **Considerations for cloud databases**

While the benefits of cloud databases can help organizations address many modern obstacles that impede growth and digital transformation, there are some common considerations of cloud databases to keep in mind as you plan your migration to the cloud [3][5][14].

* Vendor lock-in
* Difficulty integrating data with other systems
* Complex and lengthy migrations
* Underestimating cloud costs
* Possibility of connection downtime
* Cloud security concerns

The above is not necessarily a list of cloud database disadvantages, but rather factors that should be carefully weighed when selecting a cloud service provider. You'll need to take the time to evaluate the best cloud database and service model that meets your specific business needs.

At high level, your cloud database needs to take care of each and every component that traditional database needs, for e.g. CPU, RAM, Storage, Network, Security, Compliance, Data protection and Backup, and more. Plus, you need to make sure all of that is cost-effective for your company.

**1. PaaS / DBaaS vs IaaS**

This is probably the most important factor that needs to be considered. When running databases in the cloud, there are two deployment models to think about: PaaS (Platform-as-a-Service ) and IaaS (Infrastructure-as-a-Service).

In the PaaS model, the public cloud provider offers a managed database service also referred to as Database-as-a-Service (DBaaS), where most of the administrative tasks such as setting up infrastructure, backup, patching, providing SLA backed availability, and scaling up and down is taken care by the cloud provider. Depending upon your database needs, Database-as-a-Service allows you to choose between multiple sizes and performance options from the list of pre-configured instance types.

With the IaaS model, a Database can run on the infrastructure made available by the cloud service provider, also referred to as Do-it-Yourself (DIY) sometimes. The benefit of this setup is having everything under your control while still taking advantage of public cloud based infrastructure. But, it also makes you taking care of all administrative tasks which would have been taken care by cloud provider, otherwise.

**2. Data Security and Privacy**

Putting you data on cloud platforms means importance for data security goes up considerably. Data with various levels of sensitivity moves out of your company's physical infrastructure/firewall. You no longer have control and your data could reside anywhere in the world.

 Look at regulatory and privacy norms that your organization needs to adhere to and the compliance and security certifications requirements your organization has. Look for various compliance and data privacy standards for which the cloud provider is certified; for example, GDPR, PCI, HIPAA, SOC, and ISO 27001 etc. In addition, look for various commitments on disclosure of data and how it will be shared with the client and regulatory bodies.

Robust security features are paramount. Any database model you select should be able to perform data encryption at rest and in flight and provide automated security updates. It is also essential to ensure a strict separation of duties so operations cannot access customer data. Strong data redaction capabilities help ensure that visibility to sensitive data is limited and controlled. External attack detection and prevention driven by machine learning provides an additional layer of real-time security. Lastly, for your most business-critical applications, you’ll want a dedicated cloud infrastructure that includes hardware isolation from other tenant

**3. High Availability**

To ensure business continuity, it is important that your cloud database is highly available and resilient to disasters or infrastructure failures. A cloud database instance should be configured for High Availability with a primary instance and a standby instance.

When you are running databases in the cloud for high availability and you need to meet all the compliance requirements, you should always consider setting up your DBaaS in Multiple Availability Zones.

**4. Scalability**

Any cloud solution worth its salt will offer ultimate flexibility when scaling to your business requirements. It should adapt when you need it to, without you needing to be forward-thinking and have too many plans.

So, when choosing the cloud database, think about over the time as well as seasonal trends your usage and traffic will increase. Your database on cloud should be able to support that by scaling both compute and storage.

1. **Data Repatriation**

Data has stickiness for various reasons and usually not all data for an enterprise is located at same place. You should consider the cost to bring data from one environment to the other. And you cloud provider should incorporate flexibility in terms of bringing the data back into on-premise from private or public cloud environments and vice versa.

**7. Data Migration**

Data retrieval and migration without the proper provisions may become challenging from a cost and support perspective. Could database provider should provide mechanism, tools and support for data migration.

**8. Backup and Disaster Recovery**

When it comes to downtime, data breaches or any other security issue, every business should have a prevention plan. But this is only one piece of the puzzle. You also need to focus on disaster recovery if the worst were to happen.

Your cloud database should enable automated backups for high availability. Even better Backup-as-a-Service, a separate service that keeps your data safe and recoverable, should a disaster occur.

**9. Cloud Database Management Tool**

Cloud database management system is a distributed database that delivers computing as a service. Cloud provider should provide you with Console and Tools for you to be able to manage your database, as you need.

**10. Cost**

The summary of the cost discussion is that there is no one-size fits all and that careful consideration should take place before making a selection of the right cloud platform. The term ‘right-sizing’ is often referred to when it comes to the economics of cloud hosting.

If your virtual server options come in three sizes, but your application requires a size somewhere in between, you still end up paying for the additional resources you are not using. This is the typical scenario for most public clouds. Look for option where you can opt for a model that allows you to select the exact amount of resources you need now, and then scale them as you need. You might also look for Metered usage / pay-as-you-go options.

1. **Conclusion**

In this paper, we review cloud databases i.e. how database management systems offered as services in cloud .We discuss cloud database models ,it’s characteristics ,benefits and considerations of cloud databases while migrating to the cloud.

Most businesses find that maintaining their own databases can be rather expensive, so they search for alternatives that will make managing and storing data easier. Users using cloud databases can take use of a number of advantages, such as decreased total expenses for maintaining and growing the database in accordance with the needs for storing data and information, flexibility in data management, storage, and access.simple scaling, simple access since mobile devices may also be used to access cloud databases. In the event of a disaster or data theft, cloud databases provide simple and speedy recovery of data. Greater security since the data is kept safe and secure by upgraded security measures in cloud databases.

In conclusion we can say that the cloud offers you great flexibility to run your database workloads, either traditionally or as a service. Which path you choose in the cloud database vs. traditional database debate will depend on the challenges you face and what’s most important to your business. If you’re looking for a service that offloads many of the standard database and infrastructure management tasks, then you have a wide variety of options and cloud providers to choose from to get the advantages of cloud databases.

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