

Concerned About Deploying Large Microsoft® SQL Server® Databases on VMware vSphere®?

Dell Technologies can help organizations with large SQL Server database upgrades.

As application portfolios continue to grow, many organizations have turned to virtualization to achieve more cost-effective utilization of their hardware purchases. Yet many IT teams continue to run database management systems (DBMSs)—such as Microsoft® SQL Server®—on physical servers, even as the sizes of their companies' databases continue to grow. New data sources, such as the data generated by Internet of Things (IoT) devices and deep integration of operational software within organizational processes, can strain legacy versions of SQL Server running on older hardware.

Legacy databases running on outdated hardware can also pose risks for IT professionals because of discontinued technical support and security updates. For example, Microsoft will end support for SQL Server 2012 in 2022.¹ Additionally, hardware failures can lead to unplanned downtime, which can be expensive and difficult to fix. Upgrading to newer DBMS software and hardware presents its own challenges in cost and complexity.

IT teams might wonder what the best path forward is for upgrading their large SQL Server databases. An ideal solution would be to make use of virtualization technologies to run large SQL Server databases while making the most of hardware investments. To determine the impact of running large SQL Server databases in a virtualized environment, Prowess engineers used HammerDB to test how large databases perform on both older and newer versions of SQL Server, VMware vSphere®, and off-the-shelf Dell EMC™ PowerEdge™ servers. The goal of the test was to demonstrate the performance differences between older and newer hardware/software combinations, in addition to providing a benchmark that IT professionals can use to measure their own systems. This paper also examines how Dell Technologies can help organizations move their legacy SQL Server deployments to newer platforms.

Highlights

53%

Better
Microsoft® SQL Server®
performance

SQL Server 2019
performed 53.53% better
on newer hardware
and software



Convenient licensing
and support



Collaborative design
engagements for
custom solutions

Dell Technologies Provides Upgrade Paths to Microsoft SQL Server 2019

Microsoft and Dell have been working together for more than 35 years, and together they can offer IT teams simplified original equipment manufacturer (OEM) licensing for Microsoft software running on Dell EMC PowerEdge servers. Additionally, Dell Technologies provides OEM licensing for VMware software and one-stop technical support for both Microsoft and VMware software running on Dell EMC PowerEdge servers.

Prowess evaluated the option of upgrading to OEM-licensed SQL Server 2019 running on VMware vSphere and Dell EMC PowerEdge servers. As part of this evaluation, Prowess analyzed the performance of running large SQL Server 2019 databases on a newer Dell EMC PowerEdge server with Windows Server® 2019 virtual machines (VMs) and VMware vSphere 7. Prowess then analyzed the performance of running the same large databases on SQL Server 2012 running on an older Dell EMC PowerEdge server with Windows Server 2012 R2 VMs and VMware vSphere 6.7 to determine the impact that newer hardware and software and the increased number of vCPUs available in SQL Server 2019 Standard has on performance.

While running databases on physical hardware generally provides better performance than running databases in VMs, this paper offers insights into why running SQL Server 2019 in a virtual environment is beneficial, and helps IT teams know what to expect from their virtualized SQL Server 2019 deployments.

Dell Technologies and VMware® Solutions for Running SQL Server 2019

SQL Server adoption among application vendors continues to grow, which can lead to application lifecycle challenges. IT teams are often faced with SQL Server requirements that are specific to individual applications. For example, an enterprise resource planning (ERP) application might support SQL Server 2012 through SQL Server 2017, while a customer resource management (CRM) application might only support SQL Server 2017 and SQL Server 2019. For this reason, each application might rely on its own SQL Server installation, which can lead to server sprawl that complicates support, maintenance, and upgrades.

Dell Technologies and VMware have been working together as partners for nearly two decades to bring innovative virtualization solutions to organizations of any size. Combined with its multi-decade partnership with Microsoft, Dell Technologies can provide solutions that meet the needs of any size of workload, from small, single-application deployments to large deployments with thousands of applications.

The introduction of VMware vSphere 7 can help organizations consolidate their SQL Server workloads onto a pool of server hardware and storage, while also giving organizations the option of managing both on-premises and cloud deployments.

Hardware-Based Security Protects SQL Server 2019 VMs

As cyber-attacks continue to increase around the globe, IT teams are looking for hardware and software solutions to help protect their workloads. PowerEdge servers provide layers of security, from the hardware to the VM, that can help IT teams protect their critical workloads.

Security starts at the hardware level with a silicon-based root of trust. A root of trust validates a server's firmware, such as the Integrated Dell™ Remote Access Controller (iDRAC) and BIOS, as each firmware module starts. Firmware for other

server components, such as power supplies, RAID controllers, storage drives, host bus adapters (HBAs), and network interface controllers (NICs), is also validated when the server boots. Dell EMC PowerEdge servers also support Unified Extensible Firmware Interface (UEFI) Secure Boot, which validates the cryptographic signatures of UEFI drivers and other code that loads before the operating system starts. This validation is known as attestation.

Attestation creates a root of trust that helps ensure that authentic firmware is running on each individual server. vSphere supports PowerEdge security features through vSphere Trust Authority (vTA), a foundational technology introduced with vSphere 7. vTA associates a VMware ESXi™ host's hardware root of trust with virtual workloads through server attestation. If a host fails attestation, workloads are prevented from moving to that host until the problem is corrected. This security feature helps keep workloads from moving to potentially compromised servers.

Dell Technologies also offers System Lockdown mode, another important security feature of PowerEdge servers, which helps prevent malicious or inadvertent modification of server firmware and configuration. This feature is included with the iDRAC Enterprise license.

Dell EMC™ PowerStore Enhances VMware vSphere 7 Environments Running SQL Server 2019

SQL Server 2019 performance hinges on many aspects of the hardware infrastructure, but the storage type can greatly enhance or diminish database performance. Dell EMC™ PowerStore storage systems can provide performance, management, and scalability benefits to VMware vSphere 7 environments running SQL Server 2019, while helping to reduce administrative overhead.

Dell EMC PowerStore standard features include:

- **VMware vSphere integration:** Dell EMC PowerStore provides deep integration with VMware vSphere 7, including support for VMware vSphere Storage APIs Array Integration (VAAI), APIs for Storage Awareness (VASA), snapshot management, and VMware vSphere® Virtual Volumes™ (vVols) storage containers. Dell EMC PowerStore also offers AppsOn, a unique solution for smaller enterprises or edge environments that lets VMware administrators run VMs directly on PowerStore using an embedded VMware ESXi hypervisor.
- **Data-reduction features:** Dell EMC PowerStore helps enterprises save on storage costs with built-in data-reduction features, including deduplication and data compression. These data-reduction techniques are always active and are applied to all incoming data. A smaller data footprint can lead to cost savings through a reduced storage device footprint, in addition to data center power and cooling savings.
- **Thin provisioning:** This always-active Dell EMC PowerStore feature helps optimize storage space use. Thin provisioning lets administrators specify a maximum amount of storage for a resource, such as a virtual machine, block storage, or file share. The PowerStore appliance allocates only a portion of the requested amount, and then allocates physical storage as needed when data is written. This on-demand allocation of physical storage helps optimize the available storage space.
- **Snapshot capabilities:** Snapshots are point-in-time, space-efficient copies of data stored in volumes, file systems, and VMs that can help protect data from accidental deletion or data corruption. Dell EMC PowerStore snapshots are based on redirect-on-write technology. When a write request is made to a snapshot, PowerStore directs the data to a new location on the physical storage and updates references to the snapshot to point to the new location. Using this method reduces physical storage space for snapshots and provides an easy process to restore corrupted or deleted data.

Dell EMC PowerStore also offers scale-up and scale-out capabilities. As VMware vSphere or SQL Server needs increase, enterprises can scale by adding additional capacity to PowerStore appliances, or by clustering multiple PowerStore appliances for greater performance and capacity.

Benefits of Running SQL Server 2019 on VMware vSphere 7

Running SQL Server 2019 on VMware vSphere 7 provides a number of advantages over running SQL Server 2019 on bare-metal hardware. These advantages include:

- **Better optimization of hardware resources:** Running SQL Server 2019 on physical hardware can lead to hardware underutilization. Running the same workloads on vSphere can lead to better hardware utilization as multiple SQL Server VMs can run on a pool of hardware instead of a single SQL Server deployment running on a physical server. Better hardware utilization can help lead to a lower total cost of ownership (TCO).
- **High-availability capabilities:** While SQL Server 2019 provides high-availability options through Always On availability groups and SQL Server clustering, vSphere also provides fault tolerance and high-availability capabilities that can be used with the high-availability features of SQL Server 2019 to provide layers of protection for critical applications.
- **Better SQL Server performance management:** VMware vSphere® vMotion® allows virtual machine (VM) migration between physical hosts, either within a data center or across multiple data centers. Migrating VMs with the VMware vSphere® Distributed Resource Scheduler™ (DRS) lets vSphere automatically balance SQL Server workloads across the infrastructure. If a SQL Server workload begins experiencing CPU pressure on a host with multiple VMs with high CPU usage, vSphere DRS will automatically migrate the SQL Server workload to a host with more CPU overhead, without any disruption to users or applications. Additionally, VMware vSphere® Storage vMotion® seamlessly moves SQL Server VMs across storage devices to help balance storage performance.

For a more in-depth discussion of vSphere and SQL Server best practices, see

["Architecting Microsoft SQL Server on VMware vSphere®: Best Practices Guide."](#)

VMware vSphere 7 also introduces a number of key features and improvements that can simplify and enhance SQL Server 2019 deployment and management in a Dell EMC PowerEdge environment. Some of these features include:

- **Enhanced VMware vSAN™ capabilities:** VMware vSAN is a software-defined storage (SDS) solution for hyperconverged infrastructure (HCI) that provides features to simplify storage management and remove storage complexity. vSAN File Services extends the capabilities of vSAN by letting administrators provision file shares, in addition to block storage. vSAN 7 also enhances file shares for cloud-native applications, which enables greater efficiencies for applications that use files. These features and more are fully supported by Dell EMC™ vSAN Ready Nodes, which are PowerEdge servers preconfigured, tested, and certified to run vSAN.
- **VMware vSphere Lifecycle Manager (vLCM):** vLCM lets IT teams standardize server configurations across servers within a vSphere cluster. Infrastructure administrators can create images at the cluster level that define how servers within the cluster are configured. These images can include attributes such as the vSphere hypervisor (VMware ESXi) release and add-ons that let vLCM communicate with vendor-provided management tools, such as Dell EMC™ OpenManage™ Integration for VMware vCenter® (OMIVV). This integration also lets administrators manage server and management firmware across the cluster.

This is just a sampling of what vSphere 7 has to offer. For more information, see

["vSphere 7 – Announcing General Availability of the New Generation of vSphere."](#)

Dell Technologies Simplifies Microsoft and VMware Licensing and Support

For many IT teams, keeping track of software product licensing can be confusing and time-consuming. Purchasing software licenses is typically done through third-party resellers or directly from software vendors. But these types of purchases can lock organizations into long-term volume licensing agreements with confusing and expensive terms. In addition, working with software and hardware vendors for support issues on particular hardware and software combinations can be complex, frustrating, and time consuming.

Dell Technologies provides an easier way to manage software licenses for Microsoft and VMware products with OEM licensing. When organizations purchase a complete hardware and software solution through Dell Technologies, simplified software licensing is included as part of the purchase. Dell Technologies' pricing is competitive for organizations of all sizes, so IT teams only need to purchase the number of licenses they require.

Dell Technologies also provides simplified support for Dell Technologies hardware and OEM-licensed software. For example, suppose an organization needs help configuring SQL Server 2019 running on Windows Server 2019 and vSphere 7 for the best performance on Dell EMC PowerEdge servers. Instead of IT workers having to call Dell Technologies, Microsoft, and VMware, Dell Technologies gives organizations one number to call for OEM-licensed products and Dell Technologies hardware.

Additionally, Dell Technologies provides downgrade options for SQL Server. If an application requires SQL Server 2017 or SQL Server 2016, Dell Technologies and Microsoft can provide downgrade-kit options for older SQL Server versions that are still supported by Microsoft. IT teams can use these earlier versions of SQL Server until they are ready to move to SQL Server 2019.

Dell Technologies also provides Customer Solution Centers, a global network of technical labs that can help IT organizations architect, validate, and build solutions. Customer Solution Center engagements are a collaborative effort designed to find solutions to specific business requirements. These labs provide remote connectivity to the latest technology products that help IT professionals connect with solutions and Dell Technologies team members from anywhere. Customer Solutions Centers can help IT teams design proof-of-concept systems for any scenario—including large SQL Server database deployments—that incorporate best practices and the latest in hardware and software solutions.

Performance Test: SQL Server 2012 on VMware vSphere 6.7 vs. SQL Server 2019 on VMware vSphere 7

Prowess Consulting recently created a testing environment to determine how running large databases on SQL Server 2012 in vSphere 6.7 on older Dell EMC PowerEdge R730xd hardware compares to running SQL Server 2019 in vSphere 7 on newer Dell EMC PowerEdge R740xd hardware. While newer server hardware often provides performance increases for older software, Prowess wanted to measure specific performance differences between older and newer off-the-shelf hardware/software combinations. Our performance testing used industry-standard benchmarking tools.

Testing Configuration and Methodology

In typical vSphere deployments, clusters of multiple servers running the VMware ESXi hypervisor create a pool of CPU, memory, and storage for VMs. These servers, or hosts, are managed by VMware vCenter.

We tested SQL Server 2012 and SQL Server 2019 using Dell EMC PowerEdge hardware in single-server configurations with the following specifications:

- **Single-node vSphere 6.7 configuration:** The single ESXi server was managed by vCenter and was configured with a local solid-state drive (SSD) datastore for the ESXi operating system.
- **Single-node vSphere 7 configuration:** The single ESXi server was managed by vCenter and was configured with a local SSD datastore for the ESXi operating system.
- **Windows Server VMs:** The VMware vSphere 6.7 configuration contained a VM running Windows Server 2012 R2 and SQL Server 2012 Standard edition. The VMware vSphere 7 configuration contained a VM running Windows Server 2019 and SQL Server 2019 Standard edition.
 - The Windows Server 2012 R2 VM was configured with 16 vCPUs and 128 GB of RAM, while the Windows Server 2019 VM was configured with 24 vCPUs and 128 GB of RAM. Note that SQL Server 2019 Standard is licensed for up to 24 vCPUs, while SQL Server 2012 Standard is limited to only 16 vCPUs. For our tests, we used the maximum number of vCPUs for each SQL Server version.
 - Both VMs were configured with three virtual disks for the operating system, SQL Server log files, and SQL Server data and TempDB files. All virtual disks were placed on storage area network (SAN) storage and formatted with the NTFS file system, which is the default file system for Windows Server 2012 R2 and Windows Server 2019. Virtual disk sizes included 50 GB for the OS virtual disk, 31 TB for the SQL Server data virtual disk, and 7.5 TB for the SQL Server log virtual disk. All virtual disks used the VMware Paravirtual SCSI controller except for the Windows Server 2012 R2 OS virtual disk, which used an IDE controller for compatibility purposes.

The VMware vSphere 6.7 configuration consisted of a single Dell EMC PowerEdge R730xd server powered by two Intel® Xeon® processor E5-2697 v3 CPUs (14 cores, each running at 2.6 GHz) with 256 GB of DDR4 RAM. The server was equipped with dual SSDs connected to a Dell EMC™ PowerEdge RAID Controller (PERC) in a RAID 1 configuration. The server contained a Broadcom® dual-port 10 gigabit Ethernet (GbE) network adapter, a dual-port 10 GbE Intel® Ethernet Converged Network Adapter X520/I350, and a QLogic® QLE2662 16 gigabit dual-port Fibre Channel host bus adapter (HBA).

The VMware vSphere 7 configuration consisted of a Dell EMC PowerEdge R740xd server powered by two Intel Xeon Gold 6240M processors (18 cores, each running at 2.6 GHz) with 192 GB of DDR4 RAM. The servers were equipped with dual SSDs connected to a Dell EMC PERC in a RAID 1 configuration. The server contained a Broadcom dual-port 10 GbE network adapter, two dual-port 25 GbE Intel® Ethernet Network Adapter XXV710, and a QLogic QLE2742 Gen 6 dual-port Fibre Channel HBA.

The SAN storage consisted of a Dell EMC PowerStore 7000T with 50 3.5 TB NVM Express® (NVMe®) SSDs.

We used HammerDB 3.3 for the SQL Server performance tests. HammerDB is an open-source database load testing and benchmarking tool that simulates users accessing both transactional and analytical database workloads. The workloads that HammerDB uses are based on a subset of the TPC-C® specification.

HammerDB includes two measurements: transactions per minute (TPM) and new orders per minute (NOPM). TPM measures user commits plus the number of user rollbacks. The TPM measurements are database-specific, so the TPM performance values generated by HammerDB cannot be used to compare performance between different DBMSs, such as Oracle® Database versus SQL Server. Conversely, the NOPM value is based on a metric captured from within the test schema itself. Therefore, NOPM is a performance metric independent of any particular database implementation and is the more relevant metric to use for comparing performance among different DBMSs.

Testing Plan

We conducted performance tests specific to SQL Server running HammerDB three times for 20 minutes each with the configurations shown in Table 1. Each set of tests were run on both the SQL Server 2012 and SQL Server 2019 configurations.

Table 1. HammerDB test configurations for the 20 TB and 30 TB databases

Database Size	Warehouses	Transactions	User Count
20 TB	1,000	1,000,000	50
	1,000	1,000,000	100
	1,000	1,000,000	500
	1,000	1,000,000	1,000
30 TB	1,000	1,000,000	50
	1,000	1,000,000	100
	1,000	1,000,000	500
	1,000	1,000,000	1,000

After each test, we deleted and then restored the test database. We took the variance of the three passes to ensure that they were within plus-or-minus five percent of each other.

Testing Optimizations

We performed the following optimizations before conducting the HammerDB tests:

- **Configure the max_server_memory setting:** SQL Server 2019 automatically allocates all available RAM to the SQL Server process. Under some conditions, SQL Server 2019 might use memory that is needed by the operating system or other applications, which can lead to performance degradation due to disk paging. The max_server_memory setting lets administrators manually restrict the amount of memory that SQL Server 2019 accesses, which leaves memory available for other processes. More information about max_server_memory can be found in this [Microsoft article](#).
- **Configure Lock Page in Memory (LPIM):** This setting is applied to the SQL Server service account and prevents Windows Server from paging SQL Server buffer pool pages to disk.

Test Results

Figures 1–4 (in addition to Table 2) provide the results of our 20 TB and 30 TB database tests using HammerDB. Each chart compares the performance between SQL Server 2012 running on a single Windows Server 2012 R2 VM with

VMware vSphere 6.7 running on a PowerEdge R730xd server (configuration 1), and SQL Server 2019 running on a single Windows Server 2019 VM with VMware vSphere 7.0 running on a PowerEdge R740xd server (configuration 2). For complete configuration details, see the [“Testing Configuration and Methodology”](#) section of this paper.

Configuration 1 uses older server hardware, an older version of VMware vSphere, and SQL Server 2012, which is limited to 16 vCPUs. Configuration 2 uses newer server hardware, a newer version of VMware vSphere, and SQL Server 2019, which is licensed for up to 24 vCPUs. Due to the higher virtual CPU count, as well as differences in hardware and software, configuration 2 outperformed configuration 1.

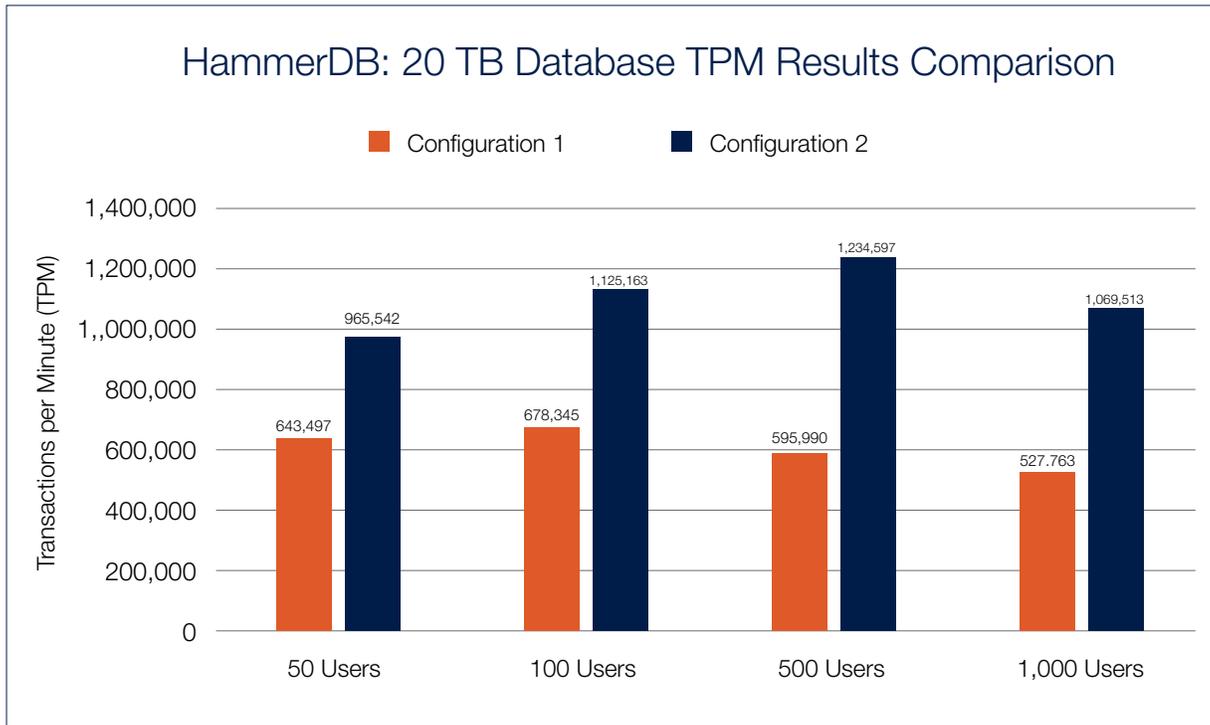


Figure 1. A comparison of HammerDB TPM scores for a 20 TB database; this chart compares the performance results between configuration 1 and configuration 2

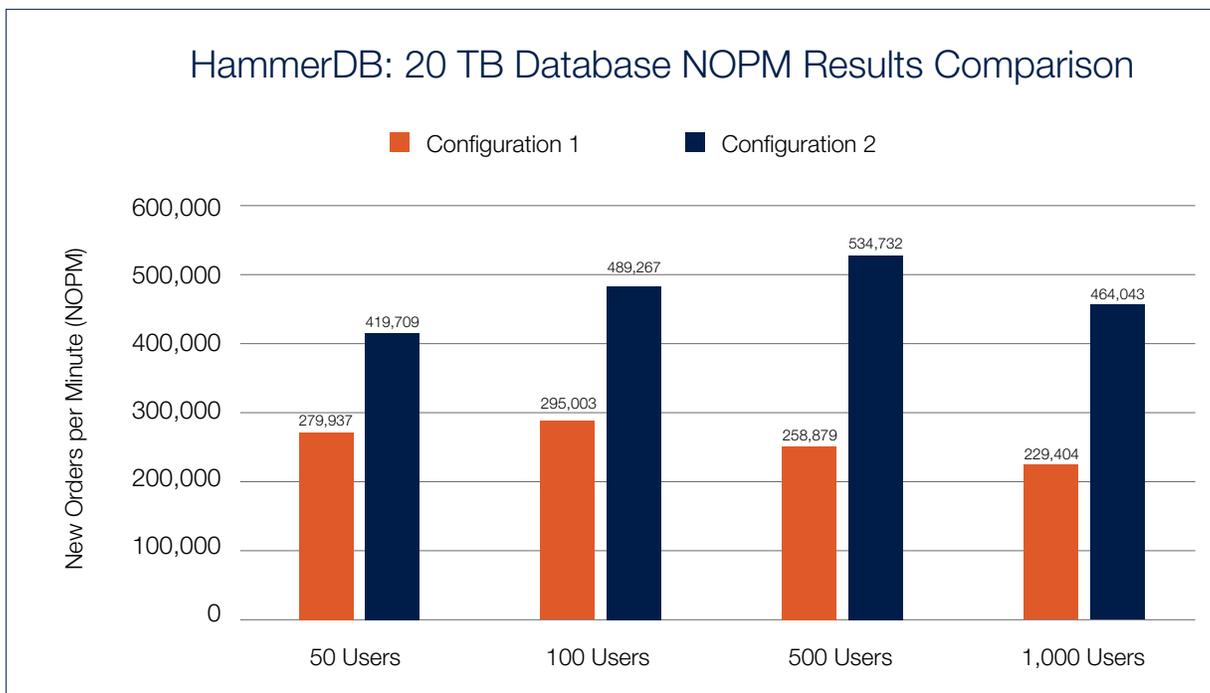


Figure 2. A comparison of HammerDB NOPM scores for a 20 TB database; this chart compares the performance results between configuration 1 and configuration 2

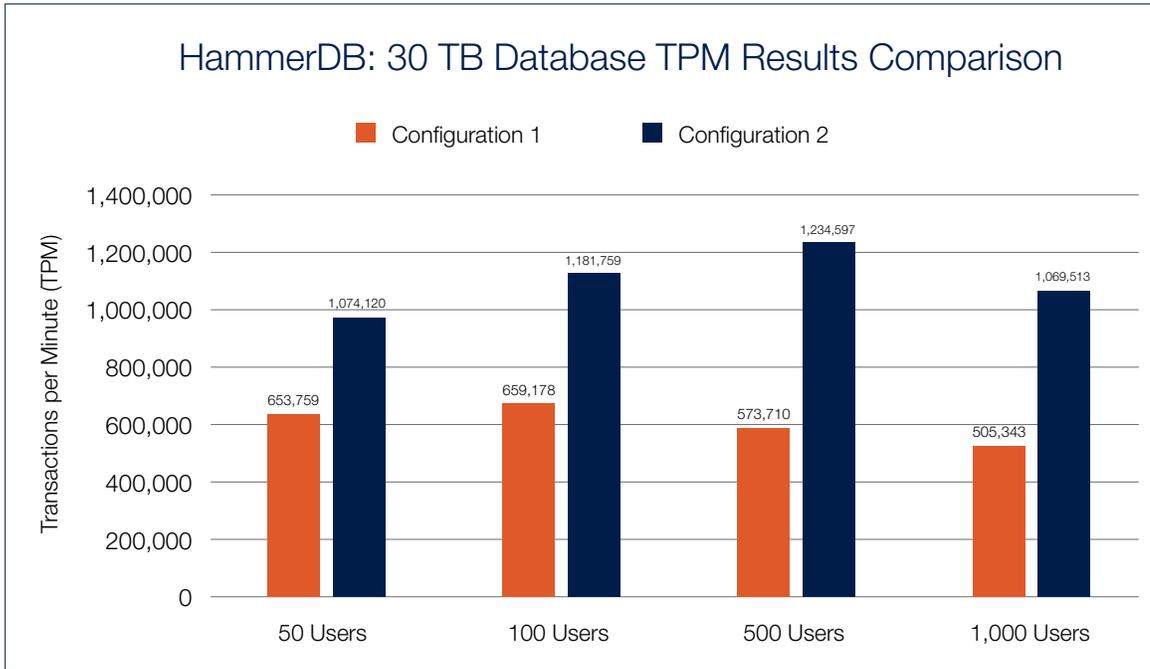


Figure 3. A comparison of HammerDB TPM scores for a 30 TB database; this chart compares the performance results between configuration 1 and configuration 2

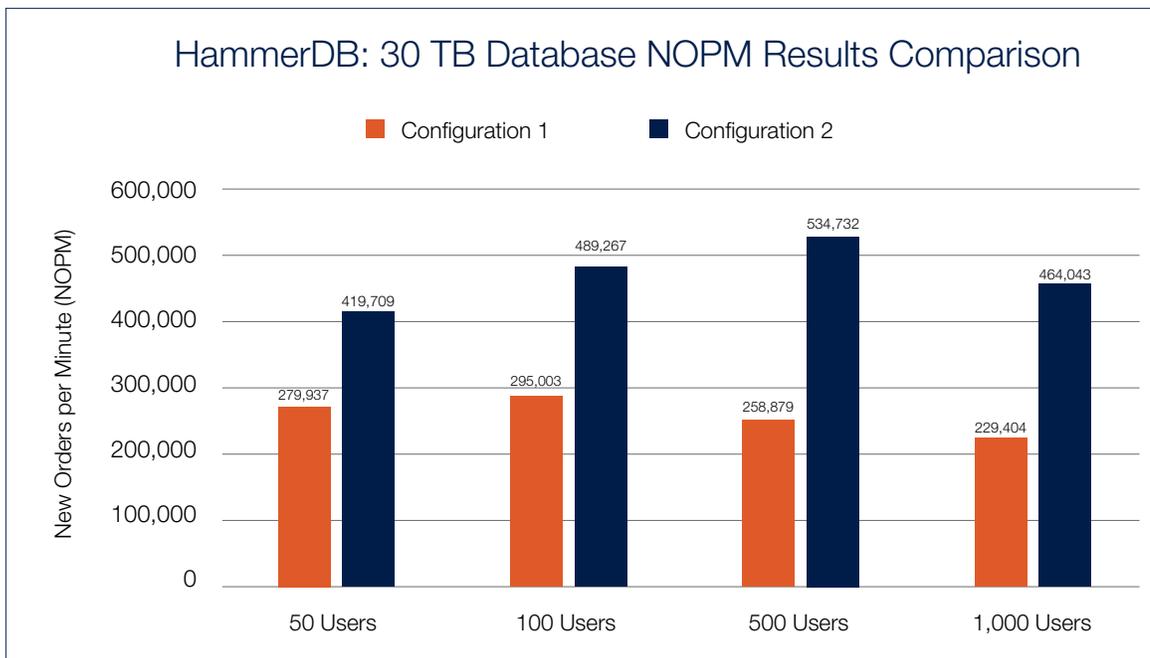


Figure 4. A comparison of HammerDB NOPM scores for a 30 TB database; this chart compares the performance results between configuration 1 and configuration 2

These results demonstrate that SQL Server 2019 running on Windows Server 2019, VMware vSphere 7, and a PowerEdge R740xd provided significantly higher database performance than SQL Server 2012 running on Windows Server 2012 R2, VMware vSphere 6.7, and a Dell EMC PowerEdge R730xd. Table 2 provides consolidated comparisons as a percentage between the two configurations. The results shown in Table 2 demonstrate that a configuration with SQL Server 2019 and VMware vSphere 7 running on newer hardware outperforms a configuration with SQL Server 2012 and VMware vSphere 6.7 running on older hardware.

Table 2. Consolidated comparison of HammerDB scores for both 20 TB and 30 TB databases; this table compares the performance results as a percentage between the two tested configurations

Number of Users	20 TB TPM Performance Difference	20 TB NOPM Performance Difference	30 TB TPM Performance Difference	30 TB NOPM Performance Difference
The newer hardware and software platform performs:				
50	33.35 percent better	33.30 percent better	39.14 percent better	33.30 percent better
100	39.71 percent better	39.71 percent better	44.22 percent better	39.71 percent better
500	51.73 percent better	51.59 percent better	53.53 percent better	51.59 percent better
1,000	50.65 percent better	50.56 percent better	52.75 percent better	50.56 percent better

The results also demonstrate that maximum performance is tied to specific load levels. We found the overall highest performance occurred on configuration 2 at a load of 500 simultaneous users and 1,000 warehouses across both the 20 TB and 30 TB NOPM and TPM performance tests. But why did performance decline on configuration 2 with 1,000 users and 1,000 warehouses? The reason behind the performance decline likely involves table lock contention, a situation that occurs when two or more simulated users attempt to perform a transaction on a warehouse whose tables are currently locked by another simulated user’s transaction.

When a simulated user in HammerDB performs a transaction on a warehouse, the DBMS locks tables within the warehouse schema until the transaction completes, which ensures data integrity. By default, each simulated user in HammerDB is randomly assigned a home warehouse when a test run begins. The simulated user performs transactions on its home warehouse only for the duration of the test run. For example, during a 50-user/1,000-warehouse test, the transactional workload will only be concentrated on 50 individual warehouses. As a result, two or more simulated users never attempt to access the same warehouse, and no table lock contention occurs.²

To increase input/output (I/O) in our test configuration, we changed this default behavior so that each simulated user is assigned a new warehouse for each transaction.³ For example, during a 50-user/1,000-warehouse test run, it is possible that the 50 simulated users could perform transactions across all 1,000 warehouses. As the ratio between users and warehouses decreases, the chances of table lock contention increase, which can significantly reduce performance. In the 1,000-user/1,000-warehouse test, there is a one-to-one ratio between simulated users and warehouses, which means that table lock contention will occur as two or more simulated users attempt to perform a transaction on a single warehouse. When this occurs, one or more of the simulated user transactions must wait until table locks are released, which leads to lower transactional performance.

Note that SQL Server performance varies depending on factors such as query complexity, indexing, database size, number of users, and cluster configuration—your results may vary.

Dell Technologies Provides Comprehensive SQL Server 2019 Solutions for Large Database Deployments

As Microsoft retires older versions of SQL Server, organizations must consider how to upgrade their legacy SQL Server deployments. Our research shows that Dell Technologies provides high-performance upgrade paths for legacy SQL Server deployments that can provide tangible performance benefits using off-the-shelf hardware and software. Newer hardware and software solutions from Dell Technologies can help IT teams run more VMs in the same rack space and more easily manage large SQL Server deployments in a virtualized environment, all while providing a layered approach to high availability. With simplified Microsoft and VMware OEM licensing and support options, in addition to Customer Solution Centers, Dell Technologies can help IT teams architect, validate, and build solutions that meet their specific business needs. For more information, visit the following sites or contact your Dell Technologies representatives.

Learn More

Dell Technologies and Microsoft solutions: www.delltechnologies.com/microsoft

Dell Technologies and VMware solutions: www.delltechnologies.com/vmware

Dell Customer Solution Centers:
www.delltechnologies.com/en-us/what-we-do/customer-engagement-programs/customer_solution_centers.htm

¹ End-of-support date according to Microsoft. Source: Microsoft. "Search Product and Services Lifecycle Information."
<https://support.microsoft.com/en-us/lifecycle/search>.

² For a more detailed explanation, see the article, "How Many Warehouses for the HammerDB TPC-C Test?" at
www.hammerdb.com/blog/uncategorized/how-many-warehouses-for-the-hammerdb-tpc-c-test/.

³ For more information about the Use All Warehouses HammerDB setting, see the section, "Use All Warehouses for increased I/O," in the HammerDB documentation at
www.hammerdb.com/docs/ch04s06.html.



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