

TPC Express Benchmark™ V Full Disclosure Report

Dell PowerEdge R7525

running

VMware vSphere 7.0.2

TPCx-V Version
Report Edition
Report Submitted

2.1.7
First
March 15, 2021

First Edition - March 2021

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Abstract


Dell conducted the TPC Express Benchmark™ V (TPCx-V) on the Dell PowerEdge R7525. The software used included VMware vSphere 7.0.2. This report provides full disclosure of the methodology and results. All testing was conducted in conformance with the requirements of the TPCx-V Standard Specification, Revision 2.1.7.

The benchmark results are summarized in the follow table.

Hardware	Software	Total System Cost (USD)	tpsV	USD/tpsV	Availability Date
Dell PowerEdge R7525	VMware vSphere 7.0.2	\$141,854	2,800.00	\$50.67	April 15, 2021

Executive Summary

The [Executive Summary](#) follows on the next several pages.

	<h2 style="margin: 0;">Dell PowerEdge R7525</h2>		TPCx-V	2.1.7
			TPC Pricing	2.6.0
			Report Date	Mar. 15, 2021
Availability Date	TPCx-V Throughput	Price/Performance	Total System Cost	
April 15, 2021	2,800.00 tpsV	\$50.67 USD / tpsV	\$141,854 USD	


System Under Test Configuration Overview

Virtualization Software	Guest VM OS	Processor Description	Memory Size
VMware vSphere 7.0.2	Red Hat Enterprise Linux release 8.3	AMD EPYC 7713 64-Core Processor	1,024 GB




1x Dell PowerEdge R7525 with:

- 2x AMD EPYC 7713 2.0 GHz (2 Proc/128 Cores/256 Threads)
- 1,024 GB (16x 64GB DIMM 3200 MHz)
- 2x Micron M.2 480 GB SATA SSD
- 12x 7.68 TB Samsung 2.5" NVMe AGN RI U.2
- 2x PERC H755N Front RAID Controller (embedded)
- 1x 1 Gb Broadcom Ethernet NIC (onboard)
- 1x Mellanox 25 Gb dual-port SFP28 Adapter

		<h1>Dell PowerEdge R7525</h1>		TPCx-V	2.1.7	
				TPC Pricing	2.6.0	
				Report Date	Mar. 15, 2021	
Description	Part Number	Key	Unit Price	Qty	Extended Price	3 yr. Maint. Price
HARDWARE COMPONENTS						
PowerEdge R7525 Server			1	\$191,918.21	1	\$191,918.21
NVMe Backplane	379-BDSX		1		1	
PowerEdge R7525 Server	210-AUVQ		1		1	
No Trusted Platform Module	461-AADZ		1		1	
16X 2.5 NVME dual PERC11, 2 CPU w XGMI	321-BGCB		1		1	
AMD 7713 2.0GHz,64C/128T,256M,225W,3200	338-BZRM		1		1	
AMD 7713 2.0GHz,64C/128T,256M,225W,3200	338-BZRO		1		1	
Additional Processor Selected	379-BDCO		1		1	
Heatsink for 2 CPU configuration (CPU greater than or equal to 180W)	412-AATC		1		1	
Performance Optimized	370-AAIP		1		1	
3200MT/s RDIMMs	370-AEVR		1		1	
No RAID/No RAID 24 + 8 dual PERC	780-BCJK		1		1	
PERC H755N Front	405-AAZE		1		1	
PERC H755N Front	405-AAZE		1		1	
Front PERC Mechanical Parts, for 2.5" x2, x8, x10, x16 SAS/SATA or 2.5" NVMe Chassis	750-ACFQ		1		1	
No Hard Drive	400-ABHL		1		1	
Performance BIOS Settings	384-BBBL		1		1	
UEFI BIOS Boot Mode with GPT Partition	800-BBDM		1		1	
Standard Fan x6	750-ACSP		1		1	
Dual, Hot-Plug,Power Supply Redundant (1+1), 1400W ART	450-AJHI		1		1	
Riser Config 4, Half Length, 6x8, 2x16 slots	330-BBOU		1		1	
R7525 Motherboard with LOM,MLK	384-BCUP		1		1	
iDRAC9,Enterprise x5	385-BBOT		1		1	
Intel i350 Quad Port 1GbE BASE-T, OCP NIC 3.0	540-BCOE		1		1	
PowerEdge 2U Standard Bezel	325-BCHU		1		1	
BOSS-S2 controller card + with 2 M.2 480GB (RAID 1)	403-BCMB		1		1	
BOSS S2 cables and Bracket for R7525	403-BCMY		1		1	
No Quick Sync	350-BBYX		1		1	
iDRAC,Legacy Password	379-BCSG		1		1	
iDRAC Service Module (ISM), NOT Installed	379-BCQX		1		1	
iDRAC Group Manager, Enabled	379-BCQV		1		1	
VMware ESXi 6.7 U3 Embedded Image (License Not Included)	634-BRIO		1		1	
No Media Required	605-BBFN		1		1	
ReadyRails Sliding Rails	770-BBBQ		1		1	
Cable Management Arm, 2U	770-BDRQ		1		1	
No Systems Documentation, No OpenManage DVD Kit	631-AAACK		1		1	
PowerEdge R7525 Shipping	340-COFR		1		1	
R7525 Shipping Material	481-BBFE		1		1	
PowerEdge R7525 no CE or with CCC Marking	389-DUZG		1		1	
Basic Next Business Day 36 Months	709-BBFM		1		1	included
Prosupport Plus and 4Hr Mission Critical Initial, 36 Month(s)	865-BBNF		1		1	included
On-Site Installation Declined	900-9997		1		1	
64GB RDIMM, 3200MT/s, Dual Rank	370-AEVP		1		16	
7.68TB Enterprise NVMe Read Intensive AG Drive U.2 Gen4 with carrier	400-BKGU		1		12	
C13 to C14, PDU Style, 12 AMP, 6.5 Feet (2m) Power Cord	492-BBDI		1		2	
Mellanox ConnectX-5 Dual Port 10/25GbE SFP28 Adapter	540-BCMQ		1		1	
Logitech MK200 Media Keyboard and Mouse Combo	A6859396		1	\$24.99	3	\$74.97
24 Inch LED monitor VE248Q - Widescreen Full HD Monitor	A6732050		1	\$136.99	3	\$410.97
HARDWARE COMPONENTS SUBTOTAL					\$192,404.15	

(continued on the next page)

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Pricing: 1 = Dell; 2 = VMware * Discount applies to all line items where Key = 1. Discount based upon total system cost as purchased by a regular customer. Audited by Doug Johnson, InfoSizing			Three-Year Cost of Ownership: \$141,854 TPCx-V Throughput: 2,800.00 \$ USD/tpsV: \$50.67																																																									
<i>Prices used in TPC benchmarks reflect the actual prices a customer would pay for a one-time purchase of the stated Line Items. Individually negotiated discounts are not permitted. Special prices based on assumptions about past or future purchases are not permitted. All discounts reflect standard pricing policies for the listed Line Items. For complete details, see the pricing section of the TPC Benchmark Standard. If you find that the stated prices are not available according to these terms, please inform the TPC at pricing@tpc.org. Thank you.</i>																																																												


		Dell PowerEdge R7525			TPCx-V	2.1.7
					TPC Pricing	2.6.0
					Report Date	Mar. 15, 2021
Guest VM Details						
Database Manager PostgreSQL 10.15	VM Memory (Total) 978 GiB	vCPUs (Total) 432	DB Initial Size 18,725.3 GB	Configured Customers 1,400,000	Active Customers 1,400,000	
Transaction Response Times (in seconds)						
Transaction Type		Min	Avg	90 th %	Max	
Broker-Volume		0.001	0.008	0.015	1.175	
Customer-Position		0.001	0.013	0.028	4.345	
Market-Watch		0.000	0.010	0.019	2.075	
Security-Detail		0.002	0.011	0.022	2.197	
Trade-Lookup		0.001	0.045	0.079	1.490	
Trade-Order		0.002	0.018	0.036	2.499	
Trade-Result		0.002	0.024	0.045	2.232	
Trade-Status		0.001	0.009	0.019	7.664	
Trade-Update		0.006	0.072	0.126	1.647	
Data-Maintenance		0.001	0.008	0.015	0.157	
Market-Feed		0.001	0.006	0.011	0.151	
Transaction Mix						
Transaction Type		Transaction Count		Mix Percentage		
Broker-Volume		8,012,442		3.900%		
Customer-Position		30,817,135		15.000%		
Market-Watch		34,925,795		17.000%		
Security-Detail		32,871,568		16.000%		
Trade-Lookup		18,490,334		9.000%		
Trade-Order		20,750,642		10.100%		
Trade-Result		20,544,373		10.000%		
Trade-Status		36,980,277		18.000%		
Trade-Update		2,054,574		1.000%		
Data-Maintenance		1,920		N/A		
Market-Feed		115,200		N/A		
Transaction Total				205,447,140		
Measurement Interval				02:00:00		
Business Recovery Time				00:18:07		
Redundancy Level Details				Redundancy Level 1 (via RAID 10)		
Auditor				Doug Johnson, InfoSizing		

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Clause 0 – Preamble

0.1 TPC Express Benchmark™ V Overview

The TPC Express Benchmark™ V (TPCx-V) measures the performance of a virtualized server platform under a demanding database workload. It stresses CPU and memory hardware, storage, networking, hypervisor, and the guest operating system. TPCx-V workload is database-centric and models many properties of cloud services, such as multiple VMs running at different load demand levels, and large fluctuations in the load level of each VM. Another unique characteristic of TPCx-V is an elastic workload that varies the load delivered to each of the VMs by as much as 16x, while maintaining a constant load at the host level.

The TPCx-V kit is available from the TPC (See www.tpc.org/tpcx-hs for more information). Users must sign-up and agree to the TPCx-V User Licensing Agreement (ULA) to download the kit. Re-distribution of the kit is prohibited. All related work (such as collaterals, papers, derivatives) must acknowledge the TPC and include TPCx-V copyright. The TPCx-V Kit includes: TPCx-V Specification document, TPCx-V Users Guide documentation, and all software necessary to set up the benchmark environment and execute the benchmark load.

The purpose of TPC benchmarks is to provide relevant, objective performance data to industry users. To achieve that purpose, TPC benchmark specifications require that benchmark tests be implemented with systems, products, technologies and pricing that:

Are generally available to users;

Are relevant to the market segment that the individual TPC benchmark models or represents (e.g., TPCx-V models and represents multiple concurrent operating and application environments running on a platform);

Would plausibly be implemented by a significant number of users in the market segment the benchmark models or represents.

The use of new systems, products, technologies (hardware or software) and pricing is encouraged so long as they meet the requirements above. Specifically prohibited are benchmark systems, products, technologies or pricing (hereafter referred to as "implementations") whose primary purpose is performance optimization of TPC benchmark results without any corresponding applicability to real-world applications and environments. In other words, all "benchmark special" implementations that improve benchmark results but not real-world performance or pricing, are prohibited.

The rules for pricing are included in the TPC Pricing Specification.

Further information is available at www.tpc.org.

Clause 1 – General Items

1.1 Test Sponsor

This benchmark was sponsored by Dell Inc..

1.2 Configuration Diagrams

The priced configuration diagram is shown above in the [Executive Summary](#). The measured configuration diagram is shown below in Figure 1-1. In addition, any differences between the priced and the measured configurations are described.

1.2.1 Measured Configuration Diagram

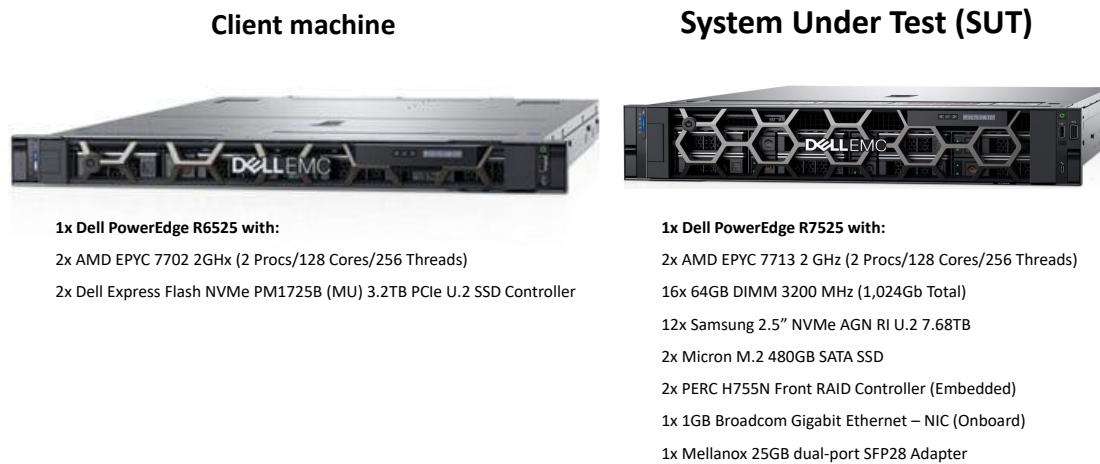


Figure 1-1 Measured Configuration

1.2.2 Differences Between the Priced and the Measured Configurations

There are no differences between the priced configuration and the System Under Test.

1.3 Hardware Setup Steps

Detailed instructions for installing and configuring the hardware used in the System Under Test (SUT) are included in the Supporting Files. Please see the [Supporting Files Index](#) for a summary of the files available.

1.4 Software Setup Steps

Detailed instructions for installing and configuring the software used in the SUT are included in the Supporting Files. Please see the [Supporting Files Index](#) for a summary of the files available.

Clause 2 – Database Design, Scaling, & Population

This section provides details of the process used to create the database environment.

2.1 Database Creation Steps

Detailed instructions for creating the database environment used in the SUT are included in the Supporting Files. Also included is the output captured from running setup.sh. Please see the [Supporting Files Index](#) for a summary of the files available.

Table 2-1 provides details on the distribution of tables, partitions, and logs across all media.

Disk #	Controller / Tile	Drives / RAID	Partition	Size	Use
1	PERC H755N Front RAID Controller (Tile 1 & Tile 2)	RAID 10	/	384 GB	OS
2	PERC H755N Front RAID Controller (Tile 1)	6x 7.68TB NVMe (RAID 10)	/pg_wal	1060 GB	DB Log
3	PERC H755N Front RAID Controller (Tile 1)	6x 7.68TB NVMe (RAID 10)	/dbstore	12,356 GB	DB Data
4	PERC H755N Front RAID Controller (Tile 1)	6x 7.68TB NVMe (RAID 10)	/backup	2,420 GB	DB Backup
5	PERC H755N Front RAID Controller (Tile 2)	6x 7.68TB NVMe (RAID 10)	/pg_wal	1,060 GB	DB Log
6	PERC H755N Front RAID Controller (Tile 2)	6x 7.68TB NVMe (RAID 10)	/dbstore	12,356 GB	DB Data
7	PERC H755N Front RAID Controller (Tile 2)	6x 7.68TB NVMe (RAID 10)	/backup	2,420 GB	DB Backup

Table 2-1 Distribution of Tables, Partitions, and Logs Across Media

2.2 Database Load Methodology

Dell used the setup.sh script provided with the TPCx-V benchmark kit to load the databases. The necessary data is generated with the required properties and loaded it into the databases. The output from the script is available in the Supporting Files. Please see the [Supporting Files Index](#) for a summary of the files available.

Clause 3 – Transactions

All transaction implementation details are handled by the TPC's TPCx-V benchmark kit. Therefore, the TPCx-V Standard Specification, Revision 2.1.7 does not have any disclosure requirements for this clause.

Clause 4 – SUT, Driver, & Network

4.1 Network Configuration Description

For the priced configuration, the SUT has 1 Gigabit Ethernet port and a dedicated iDRAC network port. Gigabit network port is connected to physical connectivity on the lab with 1000MBps speed. There is also an integrated Mellanox ConnectX-5 25GbE Dual port which is connected to driver through VMKernel switch. Port is configured with static IP to interact with driver system.

For the measured configuration, the driver has 1 Gigabit Ethernet port and a dedicated iDRAC network port. Gigabit network port is connected to Physical connectivity on the lab with 1000MBps speed. There is also a Mellanox ConnectX-5 25GbE Dual port which is connected to the SUT through VMKernel switch which has been assigned a static IP.

Another network cable is connected from the management switch to both SUT and driver which is dedicated to iDRAC.

Clause 5 – Benchmark Kit

5.1 Version

Dell used the required TPC-provided benchmark kit for this benchmark. Table 5-1 shows the version of the kit Dell used.

TPCx-V Benchmark Kit Version
2.1.7

Table 5-1 Benchmark Kit Version

5.2 Modifications

The only modifications made to the TPC-provided kit were for environment settings.

Clause 6 – Performance Metrics & Response Times

6.1 VGenDriver Configuration

6.1.1 Customer Emulator (CE)

A TPCx-V Customer Emulator (VCE) process is created by invoking `vce.jar`. The number of VCE processes is controlled by the configuration parameter `NUM_DRIVER_HOSTS` in the `vcfg.properties` file. The number of CE threads used to present the CE load to the SUT is controlled by the configuration parameter `NUM_CE_DRIVERS`.

Table 6-1 summarizes the configuration of VGenDriverCE used for this benchmark. Additional configuration details can be found in [vcfg.properties](#).

VCE Processes	5
Total CE Threads	410

Table 6-1 VGenDriverCE Configuration

6.1.2 Market Exchange Emulator (MEE)

A TPCx-V Market Exchange Emulator (VMEE) process is created by invoking `vmee.jar`. The number of VMEE processes is controlled by the configuration parameter `NUM_VMEE_PROCESSES` in the `vcfg.properties` file.

Each MEE has one thread pool for handling Trade-Result transactions and another thread pool for handling Market-Feed Transactions. The size of these thread pools is controlled by the configuration parameters `MEE_TR_POOL` and `MEE_MF_POOL`, respectively.

Table 6-2 summarizes the configuration of VGenDriverMEE used for this benchmark. Additional configuration details can be found in [vcfg.properties](#).

VMEE Processes	1
MEEs	80
Total Trade-Result Threads	400
Total Market-Feed Threads	80

Table 6-2 VGenDriverMEE Configuration

6.2 Overall Throughput

The TPCx-V Standard Specification:

- Defines Nominal Throughput as 2.00 tpsV per 1,000 Active Customers
- Requires Measured Throughput to be between 80% and 102% of Nominal Throughput
- Sets Reported Throughput to:
 - Measured Throughput when it is less than Nominal Throughput
 - Nominal Throughput when Measured Throughput is between Nominal Throughput and 102% of Nominal Throughput

Table 6-3 summarizes the overall throughput results for this benchmark.

Measured Throughput	2,853.38 tpsV	Active Customers	1,400,000
Reported Throughput	2,800.00 tpsV	80% Nominal	2,240.00 tpsV
		Nominal Throughput	2,800.00 tpsV
		102% Nominal	2,856.00 tpsV

Table 6-3 Overall Throughput Results & Nominal Throughput Summary

6.3 Measured Throughput by Group

Table 6-4 shows the measured throughput for each Group over the Measurement Interval. The TPCx-V Standard Specification requires each Group’s measured throughput to be within 2% of its expected value.

Tile	Group	Expected	tpsV	Delta
1	1	142.66	141.94	-0.50%
1	2	285.33	286.70	0.48%
1	3	428.00	421.17	-1.60%
1	4	570.67	576.91	1.09%
2	1	142.66	141.93	-0.51%
2	2	285.33	286.70	0.48%
2	3	428.00	421.15	-1.60%
2	4	570.67	576.84	1.08%

Table 6-4 Measured Throughput by Group

6.4 Test Run Graph

Figure 6-1 shows the throughput versus elapsed wall clock time for the Trade-Result transaction.

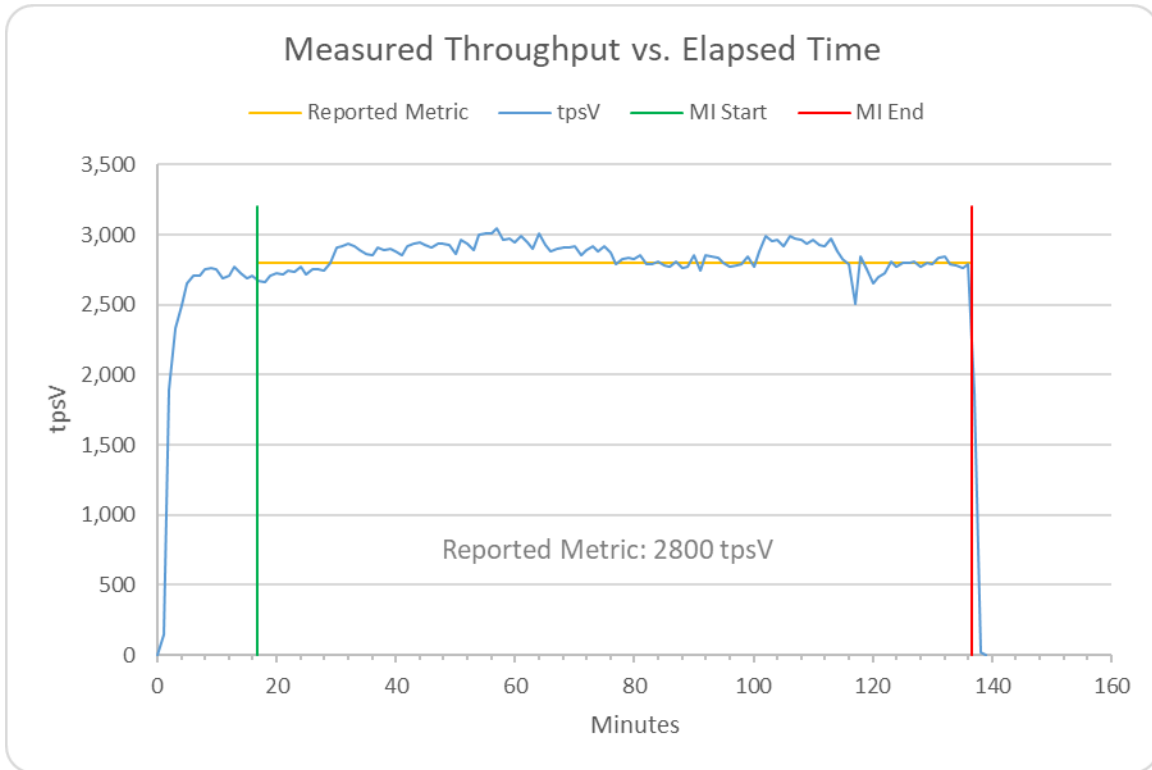


Figure 6-1 Test Run Graph

6.5 Transaction Input Parameter Mix Percentages

Table 6-5 shows the mix percentages over the Measurement Interval for key transaction input parameters.

Setting		Mix	Required Range		
Customer-Position			Min	Target	Max
By Tax ID	True	50.00%	48.00%	50.00%	52.00%
Get History	True	49.99%	48.00%	50.00%	52.00%
Market-Watch			Min	Target	Max
Security Chosen By	Watch List	60.01%	57.00%	60.00%	63.00%
	Account ID	34.99%	33.00%	35.00%	37.00%
	Industry	5.00%	4.50%	5.00%	5.50%
Security Detail			Min	Target	Max
Access LOB	True	1.00%	0.90%	1.00%	1.10%
Trade-Lookup			Min	Target	Max
Frame to Execute	1	40.01%	38.00%	40.00%	42.00%
	2	29.99%	28.50%	30.00%	31.50%
	3	20.01%	19.00%	20.00%	21.00%
	4	10.00%	9.50%	10.00%	10.50%
Trade-Order			Min	Target	Max
By Third Party	True	10.00%	9.50%	10.00%	10.50%
By Company Name	True	40.00%	38.00%	40.00%	42.00%
Buy On Margin	True	8.00%	7.50%	8.00%	8.50%
Rollback	True	0.99%	0.94%	0.99%	1.04%
LIFO	True	35.00%	33.00%	35.00%	37.00%
Trade Quantity	100	25.00%	24%	25%	26%
	200	24.99%	24%	25%	26%
	400	25.00%	24%	25%	26%
	800	25.01%	24%	25%	26%
Trade Type	Limit Buy	20.01%	19.8%	20%	20.2%
	Limit Sell	10.00%	9.9%	10%	
	Market Buy	30.00%	29.7%	30%	30.3%
	Market Sell	29.99%	29.7%	30%	30.3%
	Stop Loss	10.00%	9.9%	10%	10.1%
Trade-Update			Min	Target	Max
Frame to Execute	1	44.98%	43%	45%	47%
	2	33.03%	31%	33%	35%
	3	21.99%	20%	22%	24%

Table 6-5 Transaction Input Parameter Mix Percentages

Clause 7 – Transaction & System Properties

7.1 Atomicity

The following atomicity tests were conducted on all Tier-B VMs using the xVAudit.Atomicity application provided with the TPCx-V benchmark kit.

- Commit Test
- Rollback Test

The results of these tests are available in the Supporting Files. Please see the [Supporting Files Index](#) for a summary of the files available.

7.2 Consistency

The following consistency conditions were tested on the initial population of all Tier-B VM databases using the xVAudit.Consistency application provided with the TPCx-V benchmark kit. NOTE: these conditions are all also re-evaluated at the conclusion of the [Business Recovery](#) test.

- Consistency Condition 1
- Consistency Condition 2
- Consistency Condition 3

The results of these tests are available in the Supporting Files. Please see the [Supporting Files Index](#) for a summary of the files available.

7.3 Isolation

The following isolation tests were conducted on all Tier-B VMs using the xVAudit.Isolation applications provided with the TPCx-V benchmark kit.

- P1 Test in Read-Only
- P1 Test in Read-Write
- P2 Test in Read-Write

The results of these tests are available in the Supporting Files. Please see the [Supporting Files Index](#) for a summary of the files available.

7.4 Data Accessibility

Data Accessibility tests the SUT's ability to maintain database operations with full data access after the permanent irrecoverable failure of any single Durable Medium containing database tables, recovery log data, or database metadata.

7.4.1 Redundancy Level

Table 7-1 shows the redundancy level, as defined in the TPCx-V Standard Specification, provided by the SUT.

Redundancy Level
Level 1 – via RAID 10

Table 7-1 Redundancy Level

7.4.2 Durable Media Technologies

Table 7-2 shows the combinations of Durable Media technologies that were tested. All unique combinations (as defined by the specification) that contained database data or logs were tested.

Contents	Durable Media Type	Bus Type	Array Redundancy	Controller
Database Data (Tile1)	NVMe	SATA	RAID10	PERC H755N Front RAID Controller
Database Log (Tile1)	SSD	SATA	RAID10	PERC H755N Front RAID Controller
Database Data (Tile2)	SSD	SATA	RAID10	PERC H755N Front RAID Controller
Database Log (Tile2)	SSD	SATA	RAID10	PERC H755N Front RAID Controller

Table 7-2 Tested Durable Media Combinations

7.4.3 Test Description

Validation of Redundancy Level 1 was accomplished by performing the following steps.

- 1) The current number of completed trades, *count1*, was determined.
- 2) A test run was started using the same configuration as was used in the measured run.
- 3) The Data Accessibility Throughput Requirements were met for at least 20 minutes.
- 4) The failure was induced by physically removing a drive that contained both database data and database log. Because the array was RAID protected, the test run continued.
- 5) After a few minutes, a new drive was inserted into the disk enclosure to replace the failed drive.
- 6) The array began the necessary recovery process.
- 7) The test run continued for at least 20 minutes.
- 8) The test run terminated gracefully.
- 9) The new number of completed trades, *count2*, was determined.
- 10) The number of Trade-Results successfully completed (*count2* – *count1*) was verified to be equal to the number of successful Trade-Result transaction reported by the driver.
- 11) Successful completion of the drive recovery process was confirmed.

7.4.4 Data Accessibility Graph

Figure 7-1 shows the measured throughput versus elapsed time for the Data Accessibility test.

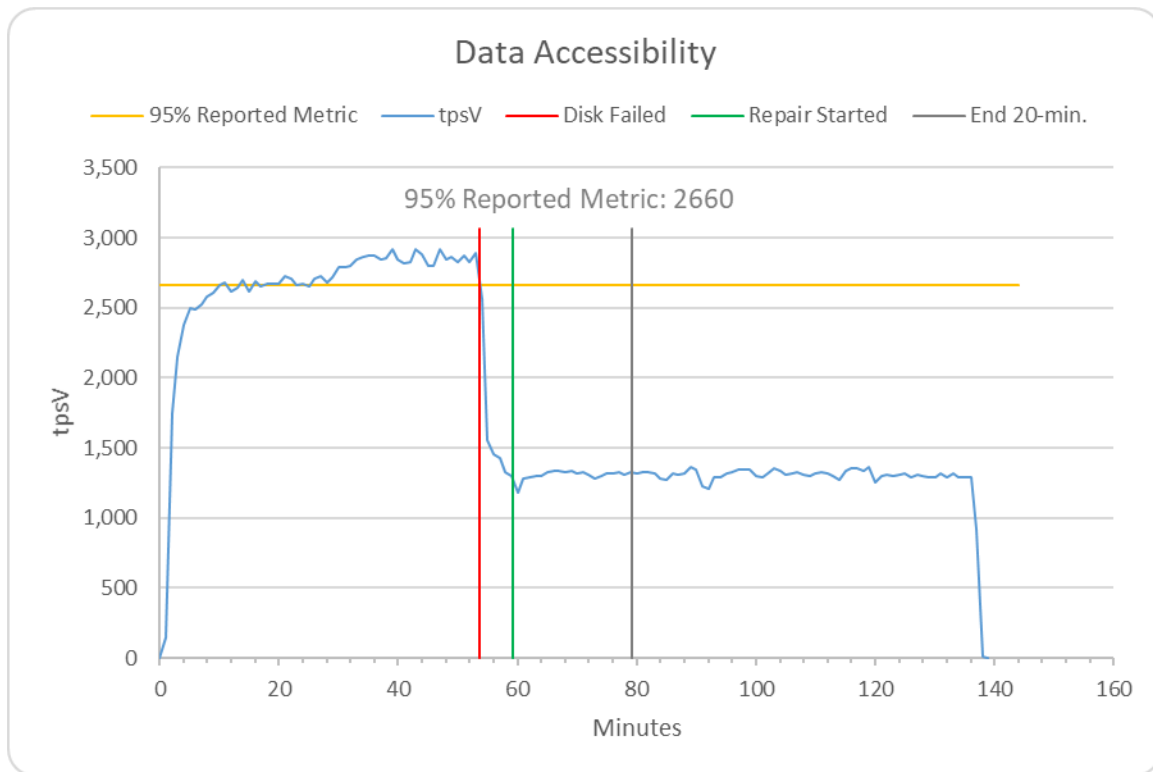


Figure 7-1 Data Accessibility Test Run Graph

7.5 Business Recovery

Business Recovery tests the SUTs ability to recover from a Loss of Processing failure as defined in the TPCx-V Standard Specification and restore certain operational criteria.

7.5.1 Test Description

Business Recovery was evaluated by performing the following steps.

- 1) The current number of completed trades, *count1*, was determined.
- 2) A test run was started using the same configuration as was used in the measured run.
- 3) The Durability Throughput Requirements were met for at least 20 minutes.
- 4) The failure was induced by instantaneously powering off Tile 1 Group 1 VM 3.
- 5) The test run was terminated.
- 6) Tile 1 Group 1 VM 3 was powered back on; Postgres was started and began automatic database recovery. The timestamp in the Postgres log for when the service started is considered the start of Database Recovery. The timestamp in the Postgres log for when the database was ready to accept connections is considered the end of Database Recovery.

- 7) A test run was started using the same configuration as was used in the measured run. The time when the driver started submitting transactions is considered the start of Application Recovery.
- 8) The run proceeded until a 20-minute window existed such that the first minute of the window and the entire window both had a tpsV that was at least 95% of the Reported Throughput. The time of the beginning of the window is considered the end of Application Recovery.
- 9) The test run terminated gracefully, and it was verified that the driver did not report any errors.
- 10) The new number of completed trades, *count2*, was determined.
- 11) The number of Trade-Results successfully completed (*count2* – *count1*) was verified to be equal to or greater than the number of successful Trade-Result transaction reported by the driver. In the case of an inequality, it was verified that the difference was less than or equal to the maximum number of Trade-Result transactions that could be simultaneously in-flight from the SUT to the driver.
- 12) Consistency of all databases was verified.

7.5.2 Business Recovery Times

Table 7-3 summarizes the key times associated with the Business Recovery test.

Event	Elapsed Time
Database Recovery	00:00:07
Application Recovery	00:18:00
Business Recovery	00:18:07

Table 7-3 Business Recovery Test Times

7.5.3 Business Recovery Time Graph

Figure 7-2 shows the measured throughput versus elapsed time for the Business Recovery test.

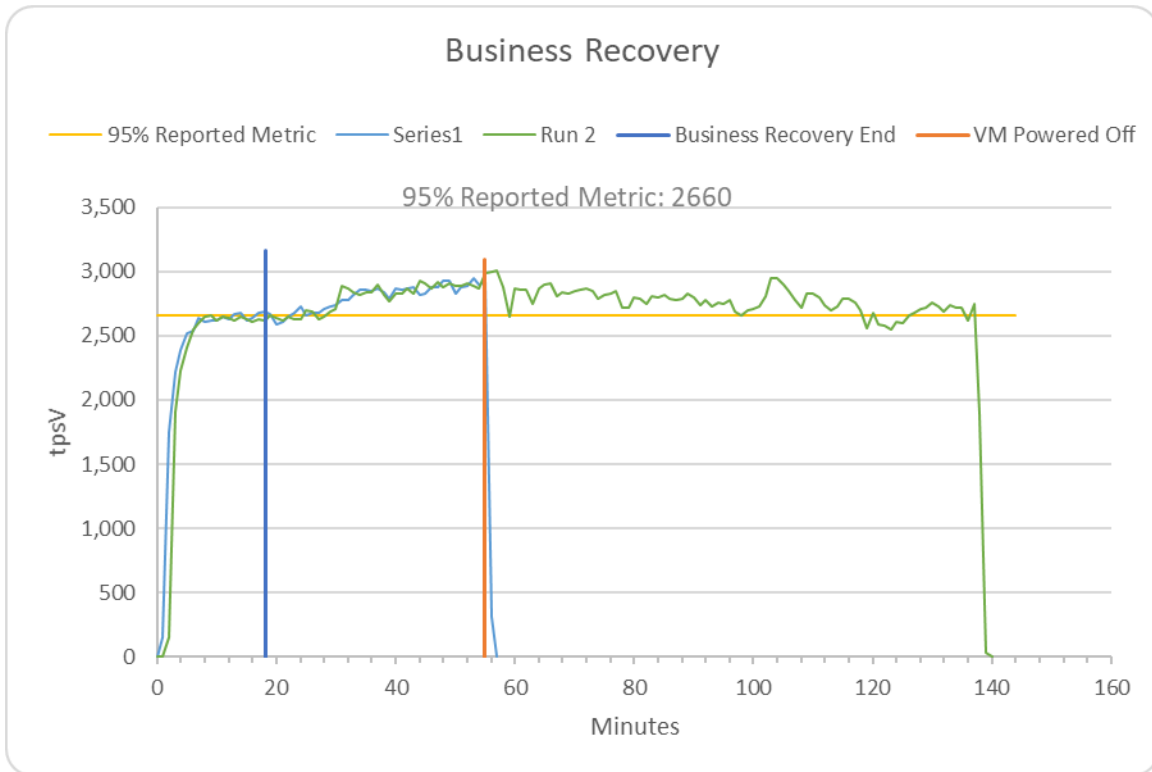


Figure 7-2 Business Recovery Time Graph

Clause 8 – Pricing

8.1 Business Day Space Calculations

To satisfy the requirements in Clauses 5.6.6.4 and 5.6.6.5 of the Standard Specification, it was verified that the file systems containing the database data and database log had at least 10% free space before and after the performance test. Details are available in the Supporting Files. Please see the [Supporting Files Index](#) for a summary of the files available.

8.2 Pricing Related Metrics

Table 8-1 contains all pricing related metrics. The total solution, as priced, will be generally available on the Availability Date.

Pricing Related Metrics	
Total Price	\$141,854
Performance Metric	2,800.00 tpsV
Price/Performance Metric	\$50.67 USD/tpsV
Availability Date	April 15, 2021

Table 8-1 Pricing Related Metrics

8.3 Additional Pricing Details

All additional pricing disclosure items, such as line item details and pricing calculations, are included in the [Executive Summary](#).

Letter of Attestation



Mohan Rokkam
 Senior Principal Engineer, PowerEdge Technical Marketing
 Dell Inc.
 1 Dell Way
 Round Rock, TX 78682

March 8, 2021

I verified the TPC Express Benchmark™ V 2.1.7 performance of the following configuration:

Platform: Dell PowerEdge R7525
 Virtualization Software VMware vSphere 7.0.2
 Guest VM OS: Red Hat Enterprise Linux 8.3

The results were:

Performance Metric 2,800.00 tpsV

Configured Customers 1,400,000
 Active Customers 1,400,000
 Tile Count 2

Server 1x Dell PowerEdge R7525

CPU	1 x AMD EPYC 7713 64-Core Processor, 2.0 GHz		
Memory	1,024 GB		
Storage	Qty	Size	Type
	2	480 GB	M.2 SATA SSD
	12	7.68 TB	NVMe

In my opinion, these performance results were produced in compliance with the TPC requirements for the benchmark.

The following verification items were given special attention:

- All TPC-provided components were verified to be version 2.1.7
- No modifications were made to the TPC-provided kit
- All databases were properly scaled and populated
- Each Group contributed the appropriate overall load to the SUT
- The mandatory network between the driver and the SUT was configured
- The ACID properties were met
- Input data was generated according to the specified percentages

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- All 90% response times were under the specified maximums
- The measurement interval was 120 minutes
- The implementation used Redundancy Level 1
- The Business Recovery Time of 00:18:07 was correctly measured
- The system pricing was verified for major components and maintenance
- The major pages from the FDR were verified for accuracy

Additional Audit Notes:

None.

Respectfully Yours,



Doug Johnson, Certified TPC Auditor

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Supporting Files Index

Clause	Description	Pathname
Introduction	Database tunable parameters	Introduction/vm#/DBtune.txt
	OS tunable parameters	Introduction/vm#/OStune.txt
	VM tunable parameters	Introduction/vm#/VMtune.txt
Clause 2	Log of database creation	Clause2/vm#/setup.out
Clause 4	Kit modifications	Clause4/*
Clause 5	Database growth	Clause5/mv#/DatabaseGrowth
Clause 6	ACID test output	Clause6/ACID output/*
Clause 10	Driver configuration	Clause10/vcfg.properties
	VGenLoader parameters	Clause10/create_TPCx-V_flat_files.sh
	CE VGenLogger output	Clause10/CElogger-#.log
	DM VGenLogger output	Clause10/DM_Msg-tile-group-vconn.log
	MEE VGenLogger output	Clause10/MEE_Msg-tile-group-vconn.log

Third-Party Price Quotes

The screenshot shows a web browser window displaying the VMware vSphere Standard product page. The browser's address bar shows the URL: `store-us.vmware.com/vmware-vsphere-standard-288068100.html`. The page features the VMware logo and the product name "VMware vSphere Standard" under the heading "DATA CENTER VIRTUALIZATION & CLOUD INFRASTRUCTURE". The price is listed as **\$7,390.88**. A description states: "VMware vSphere Standard provides an entry solution for basic consolidation of applications to slash hardware costs while accelerating application deployment." On the right side, there is an "Add to Cart" button, a quantity selector set to "4", a "Support Level" dropdown menu set to "Production", and a "Support Term" dropdown menu set to "3 Year". Below these options, the price **\$7,390.88** is repeated, followed by logos for various payment methods including American Express, Discover, Mastercard, Visa, and PayPal. At the bottom of the page, there are navigation links for "Store Resources", "Purchase Resources", "Additional Resources", "About", and "Connect".

vcfg.properties

This file (included here for easy reference) is also included in the Supporting Files. Please see the [Supporting Files Index](#) for a summary of the files available.

```

: '
/*
* Legal Notice
*
* This document and associated source code (the "Work") is a part of a
* benchmark specification maintained by the TPC.
*
* The TPC reserves all right, title, and interest to the Work as provided
* under U.S. and international laws, including without limitation all patent
* and trademark rights therein.
*
* No Warranty
*
* 1.1 TO THE MAXIMUM EXTENT PERMITTED BY APPLICABLE LAW, THE INFORMATION
* CONTAINED HEREIN IS PROVIDED "AS IS" AND WITH ALL FAULTS, AND THE
* AUTHORS AND DEVELOPERS OF THE WORK HEREBY DISCLAIM ALL OTHER
* WARRANTIES AND CONDITIONS, EITHER EXPRESS, IMPLIED OR STATUTORY,
* INCLUDING, BUT NOT LIMITED TO, ANY (IF ANY) IMPLIED WARRANTIES,
* DUTIES OR CONDITIONS OF MERCHANTABILITY, OF FITNESS FOR A PARTICULAR
* PURPOSE, OF ACCURACY OR COMPLETENESS OF RESPONSES, OF RESULTS, OF
* WORKMANLIKE EFFORT, OF LACK OF VIRUSES, AND OF LACK OF NEGLIGENCE.
* ALSO, THERE IS NO WARRANTY OR CONDITION OF TITLE, QUIET ENJOYMENT,
* QUIET POSSESSION, CORRESPONDENCE TO DESCRIPTION OR NON-INFRINGEMENT
* WITH REGARD TO THE WORK.
* 1.2 IN NO EVENT WILL ANY AUTHOR OR DEVELOPER OF THE WORK BE LIABLE TO
* ANY OTHER PARTY FOR ANY DAMAGES, INCLUDING BUT NOT LIMITED TO THE
* COST OF PROCURING SUBSTITUTE GOODS OR SERVICES, LOST PROFITS, LOSS
* OF USE, LOSS OF DATA, OR ANY INCIDENTAL, CONSEQUENTIAL, DIRECT,
* INDIRECT, OR SPECIAL DAMAGES WHETHER UNDER CONTRACT, TORT, WARRANTY,
* OR OTHERWISE, ARISING IN ANY WAY OUT OF THIS OR ANY OTHER AGREEMENT
* RELATING TO THE WORK, WHETHER OR NOT SUCH AUTHOR OR DEVELOPER HAD
* ADVANCE NOTICE OF THE POSSIBILITY OF SUCH DAMAGES.
*/
'
#####
#
# VM Configuration
#
# The specification defines 1 to 6 Tiles. Each Tile contains 4 Groups.
# Each Group contains 3 VMs
#
VM_GROUPS = "4"
VM_TILES = "2"
#
#####
#
# Runtime Configuration
#

```

```

# RUN_ITERATION_SEC: the combined runtime for all load phases. This value is
# divided by the number of phases to determine the run duration for each phase.
#
# For a valid run, RAMUP_SEC has to be >= 720 seconds. Included in Ramp-up is
# DRIVER_SCALEUP_SEC, which is the time to gradually log in CE threads and
# start submitting transactions. We are at full load after DRIVER_SCALEUP_SEC.
# A 30-60 second DRIVER_SCALEUP_SEC is usually adequate. After transactions
# start executing at full load, it takes 6 minutes for limit-order Trade-Results
# transactions to reach their steady-state throughput. So you want the
# difference between RAMPUP_SEC and DRIVER_SCALEUP_SEC to be at least 6 minutes
#
# DRIVER_RAMPDN_SEC: the number of seconds to ramp down the load at the end
# of the final measurement phase before terminating the run.
RUN_ITERATION_SEC = "7200"
DRIVER_SCALEUP_SEC = "60"
RAMPUP_SEC = "1000"
DRIVER_RAMPDN_SEC = "60"

VCE_POLL_PER_PHASE = "11"

# NUM_RUN_ITERATIONS: the number of times to run a full set of all load phases
# NUM_RUN_PHASES: the number of load phases in a single run iteration
NUM_RUN_ITERATIONS = "1"
NUM_RUN_PHASES = "10"

#
#####

#####
#
# VDriver Configuration
#
# VDriver (prime) hostname and RMI listening port
VDRIVER_RMI_HOST = "pdriver"
VDRIVER_RMI_PORT = "62140"
#
#####

#####
#
# VCe Configuration
#
# NUM_DRIVER_HOSTS: the number of CE *processes* (i.e. how many invocations of
# vce.jar) that you want to drive load against the SUT. A value of 1 usually
# suffices, unless you need to drive the load from multiple driver systems
NUM_DRIVER_HOSTS = "5"

# Default and index-specific VCe driver hostnames and ports for RMI
# communication between processes (These let the VDriver process know where to
# contact the VCE processes to send benchmark control commands). There must be
# one host/port pair combination for each NUM_DRIVER_HOSTS (additional entries
# are ignored).
VCE_RMI_HOST[] = "pdriver"
VCE_RMI_PORT[] = "63240"

# Indexes for VCE start from 1
VCE_RMI_PORT[1] = "63240"
VCE_RMI_PORT[2] = "63241"

```

```
VCE_RMI_PORT[3] = "63242"
VCE_RMI_PORT[4] = "63243"
VCE_RMI_PORT[5] = "63244"
```

```
# NUM_CE_DRIVERS: the total number of CE threads that you want to drive load
# against the SUT VMs. If you are using multiple DRIVER_HOSTS, you can specify
# the number of CEs to start on each host by using the indexed version of this
# key. Otherwise, the CEs per host are distributed evenly between hosts.
NUM_CE_DRIVERS[] = "410"
```

```
# Indexed version. Index values start from 1
#NUM_CE_DRIVERS[1] = "2"
```

```
#####
```

```
#####
```

```
#
```

```
# VMEE Configuration
```

```
#
```

```
# The number of VMEE processes the VDriver should talk to. Each VMEE spawns
# a number of "mee" threads, each of which is dedicated to a single
# Tile/Group/vconnector process
# Typically, a single VMEE process on a single system is enough, but you can
# run multiple processes, and run them from different systems
NUM_VMEE_PROCESSES = "1"
```

```
# These settings specify the host name and port number a given VMEE is
# listening on. vDriver will use these to connect to the VMEE processes. If
# starting the VMEE processes manually (i.e. not using the provided script),
# the values specified here must match those used on the VMEE command line
# (-rh and -rp) when starting a given VMEE process.
```

```
#
```

```
# Unindexed value - used as a default if a given indexed value is not specified.
```

```
VMEE_RMI_HOST[] = "pdriver"
```

```
VMEE_RMI_PORT[] = "63340"
```

```
#
```

```
# Indexed values (1 to (NUM_VMEE_PROCESSES)) will be used if they exist).
```

```
#VMEE_RMI_HOST[1] = "pdriver"
```

```
VMEE_RMI_PORT[1] = "63340"
```

```
VMEE_RMI_PORT[2] = "63341"
```

```
VMEE_RMI_PORT[3] = "63342"
```

```
VMEE_RMI_PORT[4] = "63343"
```

```
VMEE_RMI_PORT[5] = "63344"
```

```
# These settings specify individual MEE configuration options. The MEE
# threads are divided between the VMEE processes. There is a 1-1
# mapping between vconnector processes on Tier A VMs and MEEs. The
# VMEE process will have one MEE for each vconnector process
#
# MEE_TXN_HOST - host name the MEE will listen on (for connections from SUT
# SendToMarket in a vconnector process)
# MEE_TXN_PORT - port number the MEE will listen on (for connections from SUT
# SendToMarket in a vconnector process)
# MEE_MF_POOL - Size of the Market-Feed thread pool (should be 1 for TPCx-V)
# MEE_TR_POOL - Size of the Trade-Result thread pool (adjust this based on load)
#
```

```
# The indexes used for these parameters are [tile][group][vconn], indicating
```



```

# the vconnector (index) in a given group on a given tile that the MEE is
# connected to.
#
# Unindexed value - used as a default if a given indexed value is not specified.
MEE_TXN_HOST[] = "pdriver"
MEE_TXN_PORT[] = "63440"
MEE_MF_POOL[] = "1"
MEE_TR_POOL[] = "5"
#
# (Indexed values will be used if they exist. Add more entries for additional
# tiles.)
#
# Tile 1 Group 1
# MEE_TXN_HOST[1][1] = "pdriver"
# MEE_TXN_PORT[1][1][1] = "31101"
# Tile 1 Group 2
# MEE_TXN_HOST[1][2] = "pdriver"
# MEE_TXN_PORT[1][2][1] = "31201"
# Tile 1 Group 3
# MEE_TXN_HOST[1][3] = "pdriver"
# MEE_TXN_PORT[1][3][1] = "31301"
# Tile 1 Group 4
# MEE_TXN_HOST[1][4] = "pdriver"
# MEE_TXN_PORT[1][4][1] = "31401"

#####

#####
#
# VConnector Configuration
#
# VConnector is the process on the Tier A VM1 that receives transactions from
# the CE and MEE drivers, and submits them to the VM2 and VM3 databases

#
# Number of times to retry a failed DB transaction before reporting failure
NUM_TXN_RETRIES = "25"

# The "vconnector" is the process on the Tier A VM (VM1) that receives
# transactions from the driver and submits them to the database. There can be
# be one or more vconnector processes on each Tier A. NUM_VCONN_PER_GROUP
# is the number of VConnector processes running on each Tier A VM (The
# requests will be distributed across all of these processes). Each process
# is multi-threaded, and one process may be enough. But if you see odbc
# contention issues on the Tier A VM1, increase this value
NUM_VCONN_PER_GROUP = "10"

# Default VConnector hostnames and ports
VCONN_RMI_HOST[] = "pdriver"
VCONN_RMI_PORT[] = "63540"
VCONN_TXN_HOST[] = "pdriver"
VCONN_TXN_PORT[] = "63640"

# The common case is to set an unindexed CONN_DSN_LABELS[] = "PSQL2,PSQL3
# and VCONN_NUM_DBS[] = "2" to cover the whole SUT
VCONN_DSN_LABELS[] = "PSQL2,PSQL3"

```

VCONN_NUM_DBS[] = "2"

Index-specific hostnames and ports. Add more entries for additional tiles.
All host/port entries are of the form VCONN_RMI_HOST[tile][group][index]
The harness will automatically increment "index" if there are multiple
VConnector processes per group (i.e. NUM_VCONN_PER_GROUP > 1) unless values
for every tile/group/index are specified here. So the options for specifying
these values are:

#
To automatically increment port numbers for multiple VConnector processes:
#
VCONN_RMI_HOST[1][1] = "vm1"
VCONN_RMI_PORT[1][1][1] = "42000" (VCONN_RMI_PORT[1][1][1] = "42000",
VCONN_RMI_PORT[1][1][2] = "42001", ...)
VCONN_TXN_HOST[1][1] = "vm1"
VCONN_TXN_PORT[1][1][1] = "44000" (VCONN_TXN_PORT[1][1][1] = "44000",
VCONN_TXN_PORT[1][1][2] = "44001", ...)

Or, in the case of 3 VConnector processes per group, to specifically assign
values for each port (in this example, for Tile 1 Group 1):

VCONN_RMI_HOST[1][1] = "vm1"
VCONN_RMI_PORT[1][1][1] = "51100"
VCONN_RMI_PORT[1][1][2] = "32109"
VCONN_RMI_PORT[1][1][3] = "25432"
VCONN_TXN_HOST[1][1] = "vm1"
VCONN_TXN_PORT[1][1][1] = "41100"
VCONN_TXN_PORT[1][1][2] = "11243"
VCONN_TXN_PORT[1][1][3] = "27211"
#

VCONN_RMI_HOST[1][1] = "vm1"
VCONN_TXN_HOST[1][1] = "vm1"
VCONN_RMI_HOST[1][2] = "vm4"
VCONN_TXN_HOST[1][2] = "vm4"
VCONN_RMI_HOST[1][3] = "vm7"
VCONN_TXN_HOST[1][3] = "vm7"
VCONN_RMI_HOST[1][4] = "vm10"
VCONN_TXN_HOST[1][4] = "vm10"
VCONN_RMI_HOST[2][1] = "vm13"
VCONN_TXN_HOST[2][1] = "vm13"
VCONN_RMI_HOST[2][2] = "vm16"
VCONN_TXN_HOST[2][2] = "vm16"
VCONN_RMI_HOST[2][3] = "vm19"
VCONN_TXN_HOST[2][3] = "vm19"
VCONN_RMI_HOST[2][4] = "vm22"
VCONN_TXN_HOST[2][4] = "vm22"

#
#

#####

#####

#

VDM Configuration

#

VDM hostname and RMI listening port

VDM_RMI_HOST = "pdriver"

VDM_RMI_PORT = "63740"

#

The Data-Maintenance transaction is supposed to run once every 60 seconds

```

VDM_REQ_INTERVAL_SEC = "60"
#
#####

#####
#
# Group-specific Load Configuration
#
# Set CUST_CONFIGURED and CUST_ACTIVE for each Tile/Group with the index
# parameters below. SCALE_FACTOR, LOAD_RATE, and INIT_TRADE_DAYS are not
# typically changed from their defaults; the unindexed parameters should suffice
CUST_CONFIGURED[] = "5000"
CUST_ACTIVE[] = "5000"
SCALE_FACTOR[] = "500"
LOAD_RATE[] = "2000"
INIT_TRADE_DAYS[] = "125"

# Group-specific values
CUST_CONFIGURED[1] = "70000"
CUST_ACTIVE[1] = "70000"
SCALE_FACTOR[1] = "500"
LOAD_RATE[1] = "2000"
INIT_TRADE_DAYS[1] = "125"
#
CUST_CONFIGURED[2] = "140000"
CUST_ACTIVE[2] = "140000"
SCALE_FACTOR[2] = "500"
LOAD_RATE[2] = "2000"
INIT_TRADE_DAYS[2] = "125"
#
CUST_CONFIGURED[3] = "210000"
CUST_ACTIVE[3] = "210000"
SCALE_FACTOR[3] = "500"
LOAD_RATE[3] = "2000"
INIT_TRADE_DAYS[3] = "125"
#
CUST_CONFIGURED[4] = "280000"
CUST_ACTIVE[4] = "280000"
SCALE_FACTOR[4] = "500"
LOAD_RATE[4] = "2000"
INIT_TRADE_DAYS[4] = "125"

#GROUP_PCT_DIST_PHASE[1] = "1.0"

GROUP_PCT_DIST_PHASE[1] = "0.10,0.20,0.30,0.40"
GROUP_PCT_DIST_PHASE[2] = "0.05,0.10,0.25,0.60"
GROUP_PCT_DIST_PHASE[3] = "0.10,0.05,0.20,0.65"
GROUP_PCT_DIST_PHASE[4] = "0.05,0.10,0.05,0.80"
GROUP_PCT_DIST_PHASE[5] = "0.10,0.05,0.30,0.55"
GROUP_PCT_DIST_PHASE[6] = "0.05,0.35,0.20,0.40"
GROUP_PCT_DIST_PHASE[7] = "0.35,0.25,0.15,0.25"
GROUP_PCT_DIST_PHASE[8] = "0.05,0.65,0.20,0.10"
GROUP_PCT_DIST_PHASE[9] = "0.10,0.15,0.70,0.05"
GROUP_PCT_DIST_PHASE[10] = "0.05,0.10,0.65,0.20"

# Use DB_CONN_BUFFER_PCT_GROUP to modify the initial number of connections

```

```
# opened by the CEs to each Tier A VM for each group (the index value indicates
# the group number). Use values greater than 1.0 to increase the number of
# connections (up to the theoretical maximum) and values less than 1.0 to
# decrease the number of initial connections.
DB_CONN_BUFFER_PCT_GROUP[1] = "1.5"
DB_CONN_BUFFER_PCT_GROUP[2] = "1.5"
DB_CONN_BUFFER_PCT_GROUP[3] = "1.5"
DB_CONN_BUFFER_PCT_GROUP[4] = "1.5"
```

```
#
#####
```

```
#####
```

```
#
# Misc Configuration Parameters
# These values are unlikely to need to be modified
#
```

```
# Log names:
# CE log file names
CE_MIX_LOG = "CE_Mix.log"
CE_ERR_LOG = "CE_Error.log"
```

```
# MEE base file names for logging purposes.
MEE_LOG = "MEE_Msg"
MEE_MIX_LOG = "MEE_Mix"
MEE_ERR_LOG = "MEE_Err"
```

```
# VDM log file names
VDM_TRANSACTION_LOG = "DM_Txn"
VDM_MESSAGE_LOG = "DM_Msg"
```

```
RESULT_DIR = "results"
LOG_DIR = "."
SORT_MIX_LOGS = "0"
SORTED_LOG_NAME_APPEND = "sorted"
LOG_SAMPLE_SEC = "60"
# VGEN_INPUT_FILE_DIR = ""
DEBUG_LEVEL = "0"
SUPPRESS_WARNINGS = "1"
CHECK_TIME_SYNC = "0"
COLLECT_CLIENT_LOGS = "0"
```

```
TIME_SYNC_TOLERANCE_MSEC = "1000"
```

```
# CE_EXIT_DELAY_SEC is the number of seconds the user wants to wait to allow
# "cleanup" before final exit. This is mostly in case there are "retries" going
# on that need to have time to time out before a final exit.
CE_EXIT_DELAY_SEC = "10"
```

```
# NUM_TXN_METRICS is the number of metrics created for report purposes
NUM_TXN_METRICS = "5"
NUM_TXN_TYPES = "12"
```

```
CE_MIX_PARAM_INDEX = "1,2"
# BrokerVolumeMixLevel, CustomerPositionMixLevel,
# MarketWatchMixLevel, SecurityDetailMixLevel,
```

```
# TradeLookupMixLevel,TradeOrderMixLevel,  
# TradeStatusMixLevel,TradeUpdateMixLevel  
#CE_MIX_PARAM_1 = "0,0,0,0,0,1000,0,0"  
CE_MIX_PARAM_1 = "39,150,170,160,90,101,180,10"  
# CE_MIX_PARAM_2 = "59,130,180,140,80,101,190,20"  
# TXN_TYPE  
# "-1" = EGEN-GENERATED MIX  
# "0" = SECURITY_DETAIL  
# "1" = BROKER_VOLUME  
# "2" = CUSTOMER_POSITION  
# "3" = MARKET_WATCH  
# "4" = TRADE_STATUS  
# "5" = TRADE_LOOKUP  
# "6" = TRADE_ORDER  
# "7" = TRADE_UPDATE
```