



Dell Inc.

TPC Express Benchmark™ AI Full Disclosure Report

PowerEdge R650

with 1x PowerEdge R650; 10x PowerEdge R650
using

Cloudera CDP Private Cloud Base v7.1.7
running on

Red Hat Enterprise Linux 8.4

TPCx-AI Version
Report Edition
Report Submitted

1.0.2
First
November 30, 2022

First Edition - November 2022

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All performance data contained in this report was obtained in a rigorously controlled environment. Results obtained in other operating environments may vary significantly. No warranty of system performance or price/performance is expressed or implied in this report.

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Abstract

Dell conducted the TPC Express Benchmark™ AI (TPCx-AI) on the PowerEdge R650. The software used included Cloudera CDP Private Cloud Base v7.1.7. This report provides full disclosure of the results. All testing was conducted in conformance with the requirements of the TPCx-AI Standard Specification, Revision 1.0.2.

Configuration Overview

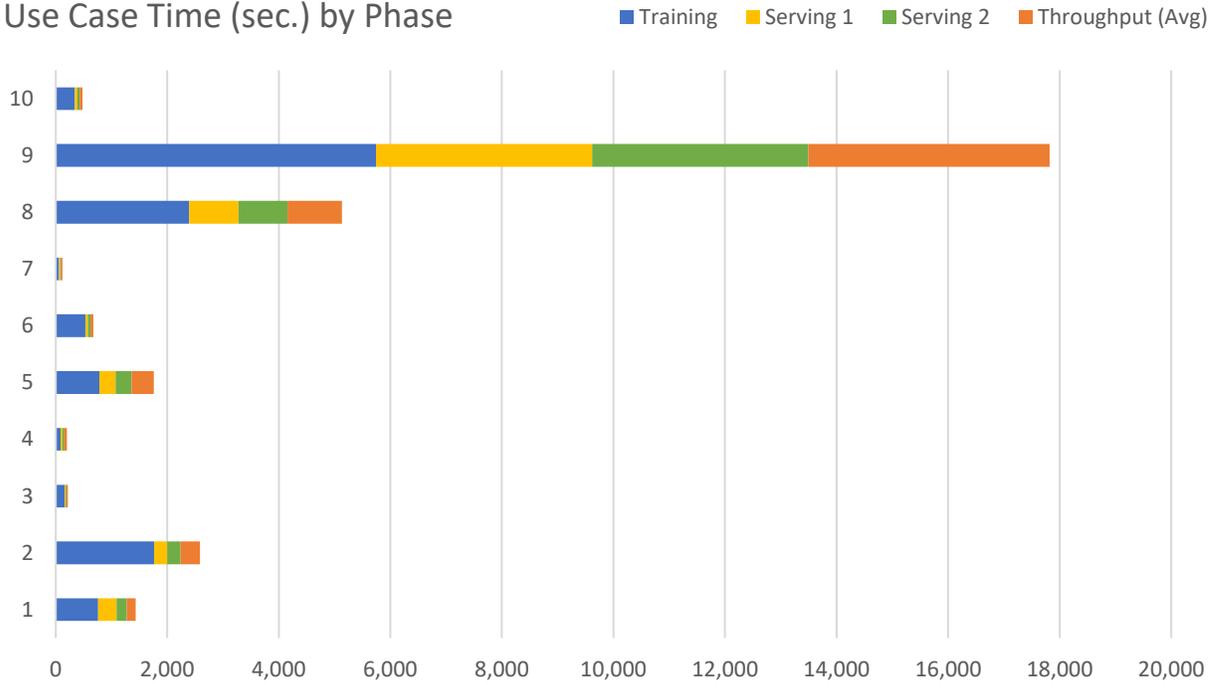
Test Sponsor	Node(s)	Operating System
Dell	1x PowerEdge R650 (Master) 10x PowerEdge R650 (Worker)	Red Hat Enterprise Linux 8.4

Metrics Overview

Total System Cost	Performance	Price/Performance	Availability Date
\$758,223 USD	2,375.83 AIUCpm@1000	319.15 USD \$/AIUCpm@1000	November 30, 2022

Executive Summary

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

		<h2>PowerEdge R650</h2>		TPCx-AI 1.0.2 TPC Pricing 2.8.0 Report Date Nov. 30, 2022
TPCx-AI Performance 2,375.83 AIUCpm@1000	Total System Cost \$758,223 USD	Price/Performance \$319.15 USD/AIUCpm@1000	Availability Date November 30, 2022	
Framework Cloudera CDP Private Cloud Base v7.1.7	Operating System Red Hat Enterprise Linux 8.4	Other Software N/A	Scale Factor 1,000	Streams 12
<h3>Use Case Time (sec.) by Phase</h3> 				
Physical Storage / Scale Factor 153.92	Scale Factor / Physical Memory 0.19	Main Data Redundancy Model Replication 3 & RAID		
Servers: Total Processors/Cores/Threads	11 22 / 616 / 1,232			
Server Type	1x PowerEdge R650 (Master)	10x PowerEdge R650 (Worker)		
Processors	2x Intel(R) Xeon(R) Gold 6348 CPU @ 2.60GHz	2x Intel(R) Xeon(R) Gold 6348 CPU @ 2.60GHz		
Memory	256 GiB	512 GiB		
Storage Controller	1x PERC H755 RAID Controller	None		
Storage Device	2x 480 GB BOSS; 4x 3.84 TB SAS SSD	2x 480 GB BOSS; 4x 3.2 TB Ent P5600 MU NVMe		
Network Controller	1x Intel Ethernet 25G 2-port E810-XXV OCP NIC	1x Intel Ethernet 25G 2-port E810-XXV OCP NIC		
Connectivity	1x Dell PowerSwitch S5212-ON 100/25 (Cluster Interconnect)			

		<h1 style="text-align: center;">PowerEdge R650</h1>			TPCx-AI	1.0.2
					TPC Pricing	2.8.0
					Report Date	Nov. 30, 2022
Description	Part Number	Source	List Price	Qty	Extended Price	1-Yr. Maintenance
Hardware						
PowerEdge R650 Server	210-AYJZ	1	\$87,099.92	10	\$870,999.20	
10x2.5 Front Storage	379-BEID	1	\$0.00	10		
NVMe Backplane	379-BDSX	1	\$0.00	10		
2x2.5 Rear Storage	379-BDTD	1	\$0.00	10		
Trusted Platform Module 2.0 V3	461-AAIG	1	\$0.00	10		
2.5" Chassis with up to 10 NVMe Drives, 2x2.5" Rear NVMe Drive	321-BGHK	1	\$0.00	10		
Intel® Xeon® Gold 6348 2.6G, 28C/56T, 11.2GT/s, 42M Cache, Tu	338-CBCI	1	\$0.00	10		
Intel® Xeon® Gold 6348 2.6G, 28C/56T, 11.2GT/s, 42M Cache, Tu	338-CBCI	1	\$0.00	10		
Heatsink for 2 CPU configuration (CPU more than 165W)	412-AAVM	1	\$0.00	10		
Performance Optimized	370-AAIP	1	\$0.00	10		
App DirectMode Intel Optane Persistent Memory 200 series	370-AGJF	1	\$0.00	10		
32GB RDIMM, 3200MT/s, Dual Rank, 16Gb BASE x8	370-AGDS	1	\$0.00	160		
128GB Optane Persistent Memory 200 Series, 3200MT/s	370-AGEX	1	\$0.00	20		
C30, No RAID for NVME chassis	780-BCDO	1	\$0.00	10		
No Controller	405-AAAD	1	\$0.00	10		
No Hard Drive	400-ABHL	1	\$0.00	10		
3.2TB, Enterprise, NVMe, Mixed Use, U2, G4, P5600 with carrier	400-BLKF	1	\$0.00	20		
3.2TB, Enterprise, NVMe, Mixed Use, U2, G4, P5600 Flex Bay	400-BLKI	1	\$0.00	20		
Power Saving Dell Active Power Controller	750-AABF	1	\$0.00	10		
UEFI BIOS Boot Mode with GPT Partition	800-BBDM	1	\$0.00	10		
4 Very High Performance Fans for 2 CPU	384-BCUJ	1	\$0.00	10		
Dual, Hot-plug, Power Supply Fault Tolerant Redundant (1+1),	450-AIQX	1	\$0.00	10		
C13 to C14, PDU Style, 12 AMP, 6.5 Feet (2m) Power Cord, Nort	492-BBDI	1	\$0.00	20		
Riser Config 6, Half Length, Low Profile, 1 x16 Slot With R1 Pad	330-BBTE	1	\$0.00	10		
PowerEdge R650 Motherboard, Barlow Pass Enabled, with Bro	329-BGKP	1	\$0.00	10		
iDRAC9 Datacenter 15G with OpenManage Enterprise Advance	528-CRVW	1	\$0.00	10		
Intel E810-XXV Dual Port 10/25GbE SFP28, OCP NIC 3.0	540-BCXW	1	\$0.00	10		
Standard Bezel for x8 and x10 Chassis	325-BCHH	1	\$0.00	10		
BOSS-S2 controller card + with 2 M.2 480GB (RAID 1)	403-BCMB	1	\$0.00	10		
No Quick Sync	350-BBXM	1	\$0.00	10		
iDRAC, Factory Generated Password	379-BCSF	1	\$0.00	10		
iDRAC Group Manager, Disabled	379-BCQY	1	\$0.00	10		
No Operating System, No Utility Partition, BOSS	611-BBBX	1	\$0.00	10		
No Media Required	605-BBFN	1	\$0.00	10		
ReadyRails Sliding Rails With Cable Management Arm	770-BDMT	1	\$0.00	10		
No Systems Documentation, No OpenManage DVD Kit	631-AAACK	1	\$0.00	10		
PowerEdge R650 Shipping	340-CUQR	1	\$0.00	10		
R650 Ship 4x3.5, 10x2.5, 8x2.5 NVMe	340-CUQN	1	\$0.00	10		
PowerEdge R650 CE CCC Marking, No BIS Marking	389-DYHZ	1	\$0.00	10		
US No Canada Ship Charge	332-1286	1	\$0.00	10		
No FGA	817-BBBB	1	\$0.00	10		
Basic Next Business Day 36 Months, 36 Month(s)	709-BBFM	1	\$200.00	10		\$2,000.00
Prosupport Plus and 4Hr Mission Critical, 36 Month(s)	865-BBNF	1	\$6,285.59	10		\$62,855.90
No Installation	900-9997	1	\$0.00	10		
Red Hat Enterprise Linux, Non Factory Install, Requires License	605-BBFL	1	\$0.00	10		
RHEL, 1-2SKT, Physical Node, 1YR Premium Sub, up to 4 Virtual	528-CHFM	1	\$0.00	10		
(continued on the next page)						

	<h1 style="text-align: center;">PowerEdge R650</h1>				TPCx-AI	1.0.2
					TPC Pricing	2.8.0
					Report Date	Nov. 30, 2022
(continued from the previous page)						
Description	Part Number	Source	List Price	Qty	Extended Price	1-Yr. Maintenance
PowerEdge R650 Server	210-AYJZ	1	\$66,799.76	1	\$66,799.76	
8x2.5 Front Storage	379-BEIC	1	\$0.00	1		
SAS/SATA Backplane	379-BDSS	1	\$0.00	1		
No Rear Storage	379-BDTE	1	\$0.00	1		
Trusted Platform Module 2.0 V3	461-AAIG	1	\$0.00	1		
2.5" Chassis with up to 8 Hard Drives (SAS/SATA), 3 PCIe Slots, 321-BGHH	321-BGHH	1	\$0.00	1		
Intel® Xeon® Gold 6348 2.6G, 28C/56T, 11.2GT/s, 42M Cache, Tu 338-CBCI	338-CBCI	1	\$0.00	1		
Intel® Xeon® Gold 6348 2.6G, 28C/56T, 11.2GT/s, 42M Cache, Tu 338-CBCI	338-CBCI	1	\$0.00	1		
Heatsink for 2 CPU configuration (CPU more than 165W)	412-AAVM	1	\$0.00	1		
Performance Optimized	370-AAIP	1	\$0.00	1		
3200MT/s RDIMMs	370-AEVR	1	\$0.00	1		
16GB RDIMM, 3200MT/s, Dual Rank	370-AEVQ	1	\$0.00	16		
C7, Unconfigured RAID for HDDs or SSDs (Mixed Drive Types A1	780-BCDS	1	\$0.00	1		
Front PERC H755 Front Load	405-AAZB	1	\$0.00	1		
3.84TB SSD SAS Read Intensive 12Gbps 512 2.5in Hot-plug AG D	400-AXPE	1	\$0.00	4		
Power Saving Dell Active Power Controller	750-AABF	1	\$0.00	1		
UEFI BIOS Boot Mode with GPT Partition	800-BBDM	1	\$0.00	1		
4 Very High Performance Fans for 2 CPU	384-BCUJ	1	\$0.00	1		
Dual, Hot-plug, Power Supply Fault Tolerant Redundant (1+1), 450-AIQX	450-AIQX	1	\$0.00	1		
C13 to C14, PDU Style, 12 AMP, 6.5 Feet (2m) Power Cord, Nort	492-BBDI	1	\$0.00	2		
Riser Config 0, 2CPU, Half Length, Low Profile, 3 x16 Slots, SW (330-BBRP	1	\$0.00	1		
PowerEdge R650 Motherboard with Broadcom 5720 Dual Port 1329-BFGW	1329-BFGW	1	\$0.00	1		
iDRAC9 Datacenter 15G with OpenManage Enterprise Advance 528-CRVW	528-CRVW	1	\$0.00	1		
Intel E810-XXV Dual Port 10/25GbE SFP28, OCP NIC 3.0	540-BCXW	1	\$0.00	1		
Standard Bezel for x8 and x10 Chassis	325-BCHH	1	\$0.00	1		
BOSS-S2 controller card + with 2 M.2 480GB (RAID 1)	403-BCMB	1	\$0.00	1		
No Quick Sync	350-BBXM	1	\$0.00	1		
iDRAC, Factory Generated Password	379-BCSF	1	\$0.00	1		
iDRAC Group Manager, Disabled	379-BCQY	1	\$0.00	1		
No Media Required	605-BBFN	1	\$0.00	1		
ReadyRails Sliding Rails With Cable Management Arm	770-BDMT	1	\$0.00	1		
No Systems Documentation, No OpenManage DVD Kit	631-AACK	1	\$0.00	1		
PowerEdge R650 Shipping	340-CUQR	1	\$0.00	1		
R650 Ship 8x2.5	340-CUQO	1	\$0.00	1		
PowerEdge R650 CE CCC Marking, No BIS Marking	389-DYHZ	1	\$0.00	1		
US No Canada Ship Charge	332-1286	1	\$0.00	1		
No FGA	817-BBBB	1	\$0.00	1		
Basic Next Business Day 36 Months, 36 Month(s)	709-BBFM	1	\$200.00	1		\$200.00
No Installation	900-9997	1	\$0.00	1		
Prosupport Plus and 4Hr Mission Critical, 36 Month(s)	865-BBMY	1	\$4,823.98	1		\$4,823.98
Red Hat Enterprise Linux, Non Factory Install, Requires License	605-BBFL	1	\$0.00	1		
RHEL, 1-2SKT, Physical Node, 1YR Premium Sub, up to 4 Virtual	528-CHFM	1	\$0.00	1		
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Pricing: 1 = Dell * 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		Total System Cost (USD): \$758,223 AIUCpm@1000: 2,375.83 \$/AIUCpm@1000: \$319.15																																																																																																																																																								
<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>																																																																																																																																																										

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			TPC Pricing	2.8.0
			Report Date	Nov. 30, 2022
<u>Numerical Quantities</u>				
AIUCpm@1000	2,375.83	T_{Load}	1,051.29	
Scale Factor	1,000	T_{LD}	1,051.29	
Streams	12	T_{PTT}	539.33	
Kit Version	1.0.2	T_{PST1}	132.23	
Execution Status	Pass	T_{PST2}	125.34	
Accuracy Status	Pass	T_{PST}	132.23	
		T_{TT}	54.26	
Test Times				
Overall Run Start Time	2022-11-13 20:48:57.882			
Overall Run End Time	2022-11-14 06:47:52.912			
Overall Run Elapsed Time	35,935.030			
Load Test Start Time	2022-11-13 21:49:52.611			
Load Test End Time	2022-11-13 22:07:26.619			
Load Test Elapsed Time	1,054.008			
Power Training Start Time	2022-11-13 22:07:26.622			
Power Training End Time	2022-11-14 01:38:09.123			
Power Training Elapsed Time	12,642.501			
Power Serving 1 Start Time	2022-11-14 01:38:09.126			
Power Serving 1 End Time	2022-11-14 03:14:33.394			
Power Serving 1 Elapsed Time	5,784.268			
Power Serving 2 Start Time	2022-11-14 03:14:33.397			
Power Serving 2 End Time	2022-11-14 04:48:31.998			
Power Serving 2 Elapsed Time	5,638.601			
Scoring Start Time	2022-11-14 04:53:08.070			
Scoring End Time	2022-11-14 04:59:06.741			
Scoring Elapsed Time	358.671			
Throughput Start Time	2022-11-14 04:59:06.748			
Throughput End Time	2022-11-14 06:47:52.911			
Throughput Elapsed Time	6,526.163			



PowerEdge R650

TPCx-AI 1.0.2
 TPC Pricing 2.8.0
 Report Date Nov. 30, 2022

Numerical Quantities (continued)

Use Case Times & Accuracy

Use Case	Training (sec)	Serving 1 (sec)	Serving 2 (sec)	Throughput (avg)	Accuracy
UC01	760.126	330.202	183.356	162.179	0.000
UC02	1,767.185	233.195	236.392	349.423	0.447
UC03	163.555	16.290	17.075	20.986	4.566
UC04	85.620	35.504	34.891	43.331	0.712
UC05	781.675	291.996	286.369	401.790	0.045
UC06	534.701	42.902	44.247	52.262	0.214
UC07	56.118	19.731	19.508	23.678	1.649
UC08	2,392.557	885.664	880.609	972.694	0.750
UC09	5,743.970	3,871.879	3,878.694	4,323.962	1.000
UC10	343.443	43.284	43.874	51.555	0.817

Use Case Serving Times (sec.)

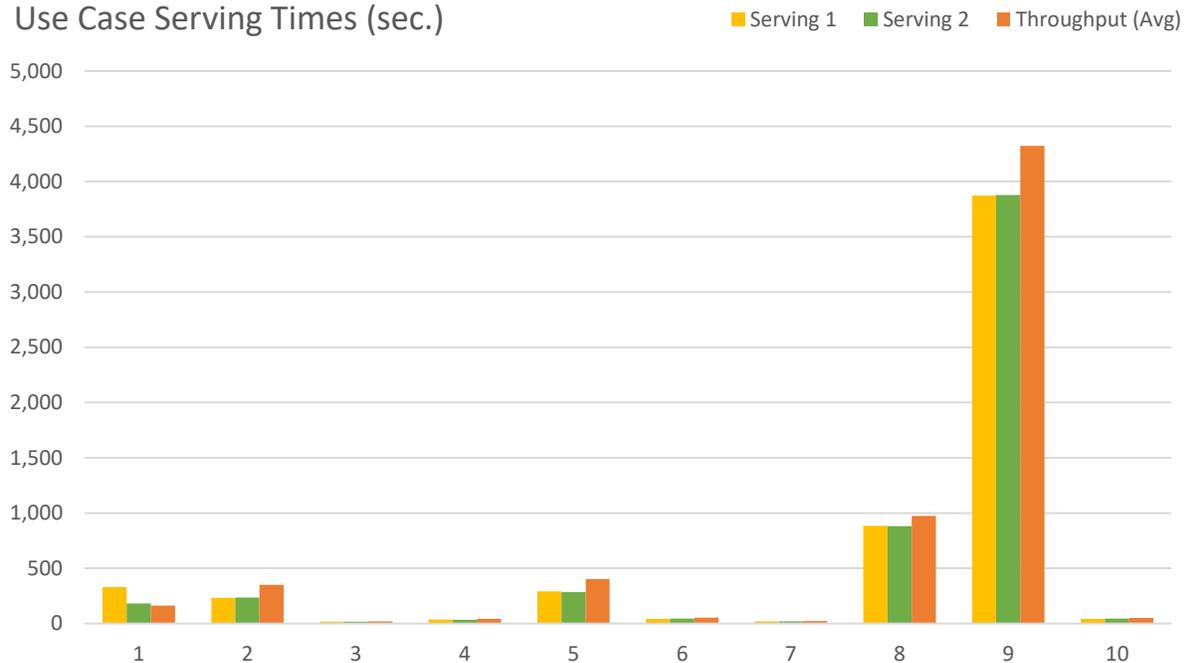


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Clause 0 – Preamble

0.1 TPC Express Benchmark™ AI Overview

Artificial intelligence (AI) has become a key transformational technology of our times. Advances in neural networks and other machine learning techniques have made it possible to use AI on a variety of use cases. From the public sector to aerospace, defense and academia, new and improved ways to use AI techniques are changing the way we harness data and analytics. This along with advances in compute, interconnect and memory technologies have made possible to solve complicated challenges that will ultimately benefit customers in production datacenter and cloud environments.

Abundant volumes of rich data from text, images, audio and video are the essential starting point for creating a benchmark that would represent the myriad of use cases and customers. TPC Express Benchmark™ AI (TPCx-AI) is created in keeping with the TPC tradition of emulating real world AI scenarios and data science use cases. Unlike most other AI benchmarks, the TPCx-AI uses a diverse dataset and is able to scale across a wide range of scale factors. TPCx-AI may later expand with additional use cases and add additional flexibility for a greater variety of implementations.

The benchmark defines and provides a means to evaluate the System Under Test (SUT) performance as a general-purpose data science system that:

- Generates and processes large volumes of data.
- Trains preprocessed data to produce realistic machine learning models.
- Conducts accurate insights for real-world customer scenarios based on the generated models.
- Can scale to large scale distributed configurations.
- Allows for flexibility in configuration changes to meet the demands of the dynamic AI landscape.

The benchmark models real-life examples of companies and public-sector organizations that use a range of analytics techniques, both AI and more traditional machine learning approaches, as well as the potential application of these techniques in situations like those in which they have already been successfully deployed. In addition, the benchmark measures end to end time to provide insights for individual use cases, as well as throughput metrics to simulate multiuser environments for a given hardware, operating system, and data processing system configuration under a controlled, complex, multi-user AI or machine learning data science workload.

The purpose of TPC benchmarks is to provide relevant, objective performance data to industry users. To achieve that purpose, TPC benchmark specifications require benchmark runs 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-AI models and represents complex, high data volume, decision support environments).
- Would plausibly be implemented.

The TPCx-AI kit is available from the TPC website (see www.tpc.org/tpcx-ai/ for more information). Users must sign up and agree to the TPCx-AI End User Licensing Agreement (EULA) to download the kit. All related work (such as collaterals, papers, derivatives) must acknowledge the TPC and include the TPCx-AI copyright. The TPCx-AI kit includes: TPCx-AI Specification document (this document), TPCx-AI Users Guide (README.md) documentation, scripts to set up the benchmark environment, code to execute the benchmark workload, Data Generator, use case related files, and Benchmark Driver.

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 Parameter Settings

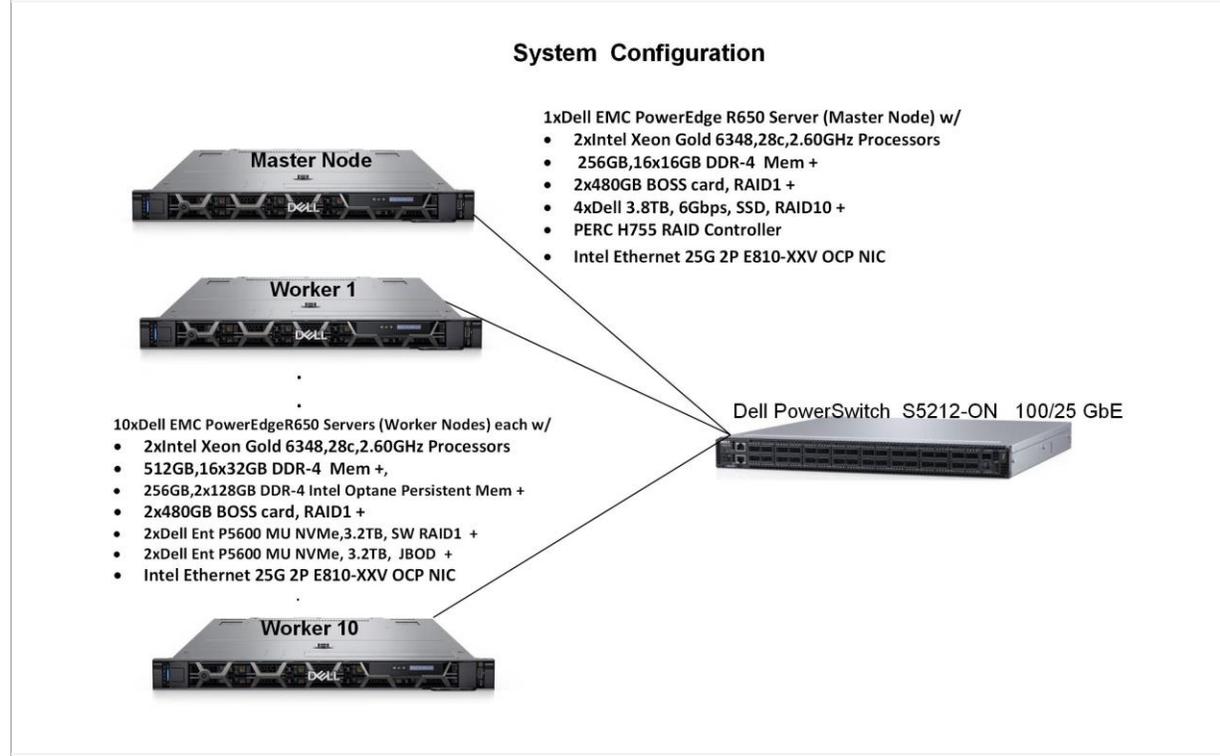
The [Supporting Files Archive](#) contains the parameters and options used to configure the components involved in this benchmark.

1.3 Configuration Diagrams

The measured configuration diagram is shown below. In addition, any differences between the measured and the priced configurations are described.

1.3.1 Measured Configuration

Nodes:	11	
Processors/Cores/Threads:	22/616/1,232	Storage Devices: 66
Total Memory:	5,376 GiB	Storage Capacity: 153,920 GB



	<u>Master</u>	<u>Worker</u>
Server	1x PowerEdge R650:	10x PowerEdge R650:
Procs/Cores/Threads:	2/28/56	2/28/56
Processor Model:	2x Intel(R) Xeon(R) Gold 6348 CPU @ 2.60GHz	2x Intel(R) Xeon(R) Gold 6348 CPU @ 2.60GHz
Memory:	256 GiB	512 GiB
Storage Controller:	1x PERC H755 RAID Controller	None
Storage Devices:	2x 480 GB BOSS 4x 3.84 TB SAS SSD	2x 480 GB BOSS 4x 3.2 TB Ent P5600 MU NVMe
Network Controller:	1x Intel Ethernet 25G 2-port E810-XXV OCP NIC	1x Intel Ethernet 25G 2-port E810-XXV OCP NIC
Network:	1x Dell PowerSwitch S5212-ON 100/25 (Cluster Interconnect);	

The distribution of software components over server nodes is detailed in [Clause 2](#).

1.3.2 Differences Between the Measured and the Priced Configurations

There are no differences between the measured configuration and the priced configuration.

Clause 2 – SW Components & Data Distribution

2.1 Roles and Dataset Distribution

Table 2-1 describes the distribution of the dataset across all media in the SUT.

Server	Host Name	Storage	Contents
1x PowerEdge R650	angeleno-icx01.fm.intel.com	2x 480 GB BOSS, RAID1 4x 3.84 TB SAS SSD, RAID10	OS Kit & Metadata
10x PowerEdge R650	fortune-icx[01-10].fm.intel.com	2x 480 GB BOSS, RAID1 2x P5600 NVMe 3.2 TB, SW RAID1 2x P5600 NVMe 3.2 TB, JBOD	OS Kit & Metadata Distributed FS

Server	Host Name	SW Services
1x PowerEdge R650	angeleno-icx01.fm.intel.com	HDFS Balancer HDFS NameNode Cloudera Management Service Reports Manager Cloudera Management Service Alert Publisher Cloudera Management Service Event Server Cloudera Management Service Host Monitor Cloudera Management Service Service Monitor YARN Queue Manager Store YARN Queue Manager Webapp Spark Gateway Spark History Server YARN JobHistory Server YARN ResourceManager ZooKeeper Server
1x PowerEdge R650	fortune-icx01.fm.intel.com	HDFS SecondaryNameNode HDFS DataNode YARN NodeManager Spark Gateway
9x PowerEdge R650	fortune-icx[02-10].fm.intel.com	HDFS DataNode YARN NodeManager Spark Gateway

Table 2-1 Software Components and Dataset Distribution

2.2 File System Implementation

A distributed file system provided by Red Hat Enterprise Linux 8.4 / Cloudera CDP Private Cloud Base v7.1.7 was used for data generation and the Load Test. The data set was not relocated after generation and before the Load Test.

2.3 Execution Engine, Frameworks, Driver & Libraries

Cloudera CDP Private Cloud Base v7.1.7 consisted of the following components.

Component	Version
HDFS	3.1.1
YARN	3.1.1
MapReduce2	3.1.1
Spark	2.4.7

Table 2-2 Software Components

For a detailed listing of installed libraries, please see the envInfo logs in the [Supporting Files](#).

2.4 Applied Patches

No additional vendor-supported patches were applied to the SUT.

Clause 3 – Workload Related Items

3.1 Hardware & Software Tuning

The [Supporting Files](#) archive contains all hardware and software configuration scripts.

3.2 Kit Version & Modifications

Table 3-1 shows the version of the TPCx-AI used to produce this result along with any kit files that were modified to facilitate system, platform, and framework differences.

TPCx-AI Kit Version	1.0.2
<u>Modified File</u>	<u>Description of Changes</u>
tools/spark/inventory	Change list of server names.
tools/parallel-data-load.sh	Enable concurrent file upload.
See Auditor’s Note	

Table 3-1 Kit Version & Modifications

3.3 Use Case Elapsed Times

Below are the elapsed times for each use case. Use cases are grouped based on whether they use Deep Learning or Machine Learning techniques.

Type	UC ID	P1	P2	T1	T2	T3	T4	T5
Deep Learning	2	233.195	236.392	266.125	335.705	263.359	321.567	323.737
	5	291.996	286.369	446.875	447.282	245.742	407.123	339.997
	9	3,871.879	3,878.694	4,332.784	4,298.248	4,380.998	4,311.183	4,332.091
Machine Learning	1	330.202	183.356	216.426	214.052	195.471	139.465	160.944
	3	16.290	17.075	19.218	22.171	20.454	25.370	19.100
	4	35.504	34.891	49.969	38.707	44.984	44.996	45.756
	6	42.902	44.247	47.134	52.120	44.445	71.096	57.573
	7	19.731	19.508	25.544	20.829	23.105	24.608	23.418
	8	885.664	880.609	985.725	967.136	942.278	947.964	951.170
	10	43.284	43.874	53.544	46.417	52.953	61.728	47.209

Type	UC ID	T6	T7	T8	T9	T10	T11	T12
Deep Learning	2	301.153	439.808	329.437	484.802	326.072	467.691	333.622
	5	405.148	422.777	482.857	244.411	518.165	410.403	450.703
	9	4,370.323	4,316.044	4,304.677	4,319.414	4,322.288	4,301.829	4,297.662
Machine Learning	1	127.273	124.878	250.308	119.353	146.962	127.614	123.396
	3	20.922	20.568	18.317	19.855	26.806	20.246	18.808
	4	41.525	34.396	41.659	43.494	41.338	47.585	45.562
	6	52.828	49.658	45.217	49.816	51.095	53.954	52.202
	7	24.059	22.570	26.436	24.283	24.219	23.321	21.741
	8	955.264	996.724	963.305	1,069.186	991.269	946.976	955.328
	10	48.659	50.236	47.926	56.470	52.385	52.479	48.659

Table 3-2 Use Case Elapsed Times

3.4 SUT Validation Test Output

<u>Validation Run Report</u>			
AIUCpm@1	14.73	T _{Load}	218.44
Scale Factor	1	T _{LD}	218.44
Streams	12	T _{PTT}	134.63
Kit Version	1.0.2	T _{PST1}	30.87
Execution Status	Pass	T _{PST2}	28.82
Accuracy Status	Pass	T _{PST}	30.87
		T _{TT}	3.03
Test Times			
Overall Run Start Time	2022-11-13 18:38:27.633		
Overall Run End Time	2022-11-13 20:31:37.846		
Overall Run Elapsed Time	6,790.213		
Load Test Start Time	2022-11-13 18:42:36.229		
Load Test End Time	2022-11-13 18:46:17.366		
Load Test Elapsed Time	221.137		
Power Training Start Time	2022-11-13 18:46:17.368		
Power Training End Time	2022-11-13 20:03:06.179		
Power Training Elapsed Time	4,608.811		
Power Serving 1 Start Time	2022-11-13 20:03:06.184		
Power Serving 1 End Time	2022-11-13 20:08:54.672		
Power Serving 1 Elapsed Time	348.488		
Power Serving 2 Start Time	2022-11-13 20:08:54.675		
Power Serving 2 End Time	2022-11-13 20:14:25.925		
Power Serving 2 Elapsed Time	331.250		
Scoring Start Time	2022-11-13 20:19:04.705		
Scoring End Time	2022-11-13 20:25:18.799		
Scoring Elapsed Time	374.094		
Throughput Start Time	2022-11-13 20:25:18.805		
Throughput End Time	2022-11-13 20:31:37.845		
Throughput Elapsed Time	379.040		
(continued on next page)			

Validation Run Report (continued)

Accuracy Metrics					
Use Case	Metric Name	Metric	Criteria	Threshold	Status
1	N/A	0.000	N/A	0.00	Pass
2	word_error_rate	0.481	<=	0.50	Pass
3	mean_squared_log_error	5.492	<=	5.40	Fail*
4	f1_score	0.697	>=	0.65	Pass
5	mean_squared_log_error	0.244	<=	0.50	Pass
6	matthews_corrcoef	0.227	>=	0.19	Pass
7	median_absolute_error	1.715	<=	1.80	Pass
8	accuracy_score	0.720	>=	0.65	Pass
9	accuracy_score	1.000	>=	0.90	Pass
10	accuracy_score	0.817	>=	0.70	Pass

*Because of the small dataset size used for the Validation Test, Spark-based implementations may not be able to satisfy the accuracy threshold for Use Case 3. The TPCx-AI Subcommittee is aware of this issue and has decided that this failure does not invalidate the test.

3.5 Configuration Parameters

The [Supporting Files](#) archive contains all Global Benchmark Parameter and Use Case Specific Parameter settings.

Clause 4 – SUT Related Items

4.1 Specialized Hardware/Software

No Specialized Hardware/Software was used in the SUT.

4.2 Configuration Files

The [Supporting Files](#) archive contains all configuration files.

4.3 SUT Environment Information

All envInfo.log files are included in the [Supporting Files](#) archive.

4.4 Data Storage to Scale Factor Ratio

The details of the Data Storage Ratio are provided below.

Node Count	Disks	Size (GB)	Total (GB)
11	2	480	10,560
1	4	3,840	15,360
10	4	3,200	128,000

Total Storage (GB)	153,920
Scale Factor	1,000
Data Storage Ratio	153.92

4.5 Scale Factor to Memory Ratio

The details of the Memory to Scale Factor Ratio are provided below.

Nodes	Memory (GiB)	Total (GiB)
1	256	256
10	512	5,120

Scale Factor	1,000
Total Memory (GiB)	5,376
SF / Memory Ratio	0.19

4.6 Output of Tests

The [Supporting Files](#) archive contains the output files of all tests.

4.7 Additional Sponsor Files

The [Supporting Files](#) archive contains any additional files that were used.

4.8 Model Optimizations

The [Supporting Files](#) archive contains any model optimization files that were used.

Clause 5 – Metrics and Scale Factor

5.1 Reported Performance Metrics

Metric Overview

TPCx-AI Performance Metric	2,375.83	AIUCpm@1000
TPCx-AI Price/Performance Metric	319.15	\$/AIUCpm@1000
TPCx-AI Scale Factor	1,000	
TPCx-AI Stream Count	12	

Test Times

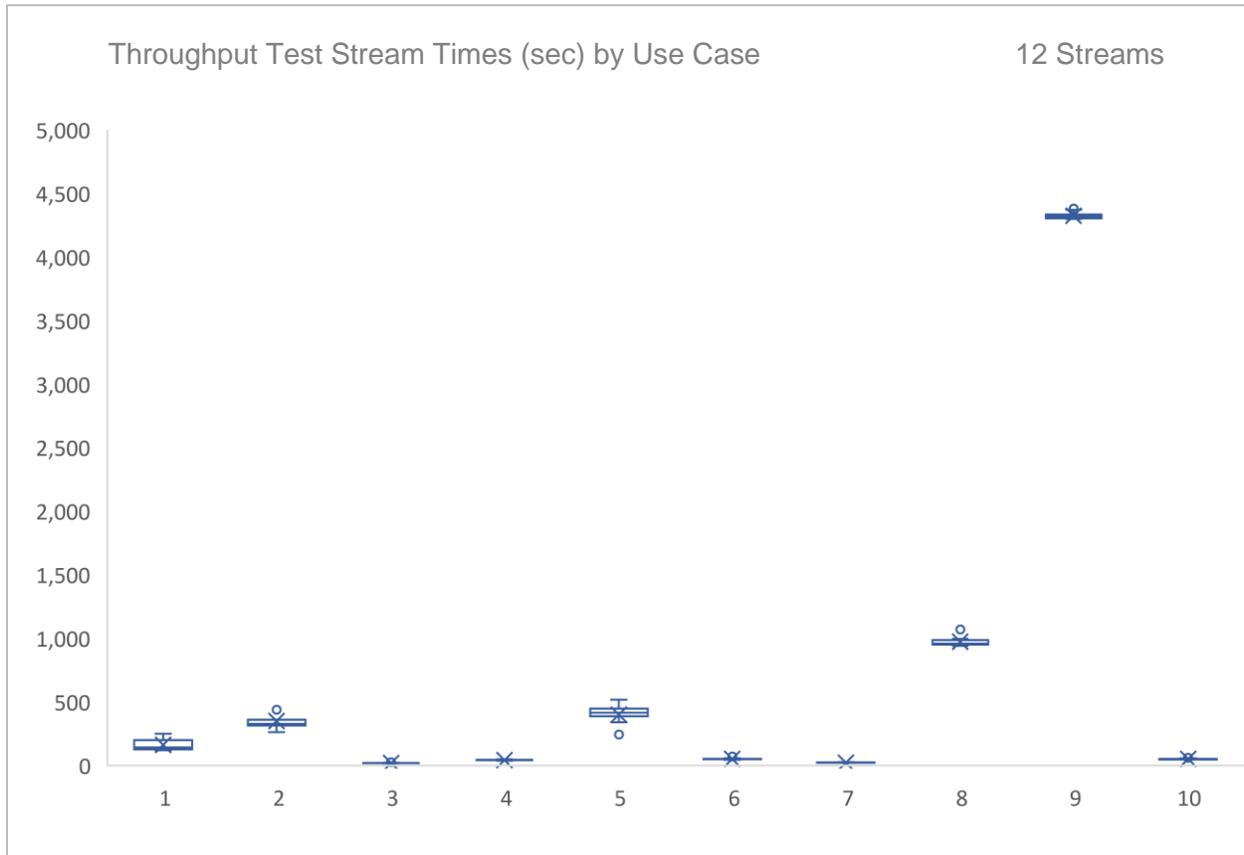
Overall Run Start Time	2022-11-13 20:48:57.882
Overall Run End Time	2022-11-14 06:47:52.912
Overall Run Elapsed Time	35,935.030
Load Test Start Time	2022-11-13 21:49:52.611
Load Test End Time	2022-11-13 22:07:26.619
Load Test Elapsed Time	1,054.008
Power Training Start Time	2022-11-13 22:07:26.622
Power Training End Time	2022-11-14 01:38:09.123
Power Training Elapsed Time	12,642.501
Power Serving 1 Start Time	2022-11-14 01:38:09.126
Power Serving 1 End Time	2022-11-14 03:14:33.394
Power Serving 1 Elapsed Time	5,784.268
Power Serving 2 Start Time	2022-11-14 03:14:33.397
Power Serving 2 End Time	2022-11-14 04:48:31.998
Power Serving 2 Elapsed Time	5,638.601
Scoring Start Time	2022-11-14 04:53:08.070
Scoring End Time	2022-11-14 04:59:06.741
Scoring Elapsed Time	358.671
Throughput Start Time	2022-11-14 04:59:06.748
Throughput End Time	2022-11-14 06:47:52.911
Throughput Elapsed Time	6,526.163

Accuracy Metrics

Use Case	Metric Name	Metric	Criteria	Threshold	Status
1	N/A	0.000	N/A	0.00	Pass
2	word_error_rate	0.447	<=	0.50	Pass
3	mean_squared_log_error	4.566	<=	5.40	Pass
4	f1_score	0.712	>=	0.65	Pass
5	mean_squared_log_error	0.045	<=	0.50	Pass
6	matthews_corrcoef	0.214	>=	0.19	Pass
7	median_absolute_error	1.649	<=	1.80	Pass
8	accuracy_score	0.750	>=	0.65	Pass
9	accuracy_score	1.000	>=	0.90	Pass
10	accuracy_score	0.817	>=	0.70	Pass

5.2 Throughput Test Stream Times

The following chart shows the minimum, 1st quartile, median, mean (X), 3rd quartile, and maximum stream times by use case for the Throughput Test. Outliers are marked with “o”.



Auditor's Information

This benchmark was audited by Doug Johnson, InfoSizing.

www.sizing.com
63 Lourdes Drive
Leominster, MA 01453
978-343-6562.

This benchmark's Full Disclosure Report can be downloaded from www.tpc.org.

A copy of the auditor's attestation letter is included in the next two pages.



Nicholas Wakou
 Dell Inc.
 701 E. Parmer Ln. Bld. 2
 Austin, TX 78753

November 29, 2022

I verified the TPC Express Benchmark™ AI v1.0.2 performance of the following configuration:

Platform: 1x PowerEdge R650; 10x PowerEdge R650
 Operating System: Red Hat Enterprise Linux 8.4
 Additional Software: Cloudera CDP Private Cloud Base v7.1.7

The results were:

Performance Metric 2,375.83 AIUCpm@1000

Secondary Metrics	T _{LD}	1,051.29
	T _{PTT}	539.33
	T _{PST}	132.23
	T _{TT}	54.26

System Under Test 1x PowerEdge R650; 10x PowerEdge R650 with:

CPU	2x Intel® Xeon® Gold 6348 CPU @ 2.60 GHz (all nodes)		
Memory	256 GiB (master); 512 GiB (workers)		
Storage	Qty	Size	Type
	2	480 GB	M.2 BOSS (all nodes)
	4	3.84 TB	SAS SSD (master)
	4	3.2 TB	NVMe (workers)

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 v1.0.2.
- All checksums were validated for compliance.
- Any modifications to shell scripts were reviewed for compliance.
- No modifications were made to any of the Java code.
- The generated dataset was properly scaled to 1,000 GB.

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- The generated dataset used for testing was protected by Replication 3 & RAID.
- The elapsed times for all phases and runs were correctly measured and reported.
- The Storage and Memory Ratios were correctly calculated and reported.
- The system pricing was verified for major components and maintenance.
- The major pages from the FDR were verified for accuracy.

Additional Audit Notes:

Because of the small dataset size used for the Validation Test, this Spark-based implementation was not able to satisfy the accuracy threshold for Use Case 3. The TPCx-AI Subcommittee is aware of this issue and has decided that this failure does not invalidate the test.

Two files were erroneously reported as having incorrect checksums. This is due to a minor issue in the TPC-provided kit. The TPCx-AI Subcommittee is aware of this and will correct it in a future release of the kit.

Respectfully Yours,



Doug Johnson, Certified TPC Auditor

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Third-Party Price Quotes

All components are available directly through the Test Sponsor (Dell).

Supporting Files Index

The Supporting Files archive for this disclosure contains the following structure.

Supporting Files Directory	Description
CheckIntegrity/...	Output of CHECK_INTEGRITY test (if the phase is not done as part of the Validation and Performance Test).
PerformanceTest/...	Performance Test output files.
ValidationTest/...	Validation Test output files.
Additional files used by Dell	
Sponsor/ModelOptimization/...	Details of model optimization.
Sponsor/ModifiedKitFiles/...	2 modified file(s).
Sponsor/Tuning/...	All tuning files used.