TPC Benchmark™ E
Full Disclosure Report
for
IBM® System x® 3850 X5
using
Microsoft® SQL Server 2008 R2
Enterprise Edition
and
Microsoft Windows® Server 2008 R2
Enterprise Edition SP1

TPC-E Version 1.12.0

First Edition
Submitted for Review
August 26, 2011
**Trademarks**

IBM, the IBM logo, System x, and System Storage are trademarks or registered trademarks of International Business Machines Corporation.

The following terms used in this publication are trademarks of other companies as follows: TPC Benchmark, TPC-E, tpsE, and $/tpsE trademark of Transaction Processing Performance Council; Intel and Xeon are trademarks or registered trademarks of Intel Corporation; Microsoft and Windows are trademarks or registered trademarks of Microsoft Corporation. Other company, product, or service names, which may be denoted by two asterisks (**), may be trademarks or service marks of others.

**Notes**

1 GHz and MHz only measures microprocessor internal clock speed, not application performance. Many factors affect application performance.

2 When referring to hard disk capacity, GB, or gigabyte, means one thousand million bytes. Total user-accessible capacity may be less.
Abstract

IBM Corporation conducted the TPC Benchmark™ E on the IBM® System x®3850 X5 configured as a client/server system. This report documents the full disclosure information required by the TPC Benchmark E Standard Specification, Revision 1.12.0, including the methodology used to achieve the reported results. All testing fully complied with this revision level.


Standard metrics, transactions per second-E (tpsE), price per tpsE ($/tpsE) and Availability Date, are reported as required by the TPC Benchmark E Standard Specification.

The benchmark results are summarized in the following table:

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Software</th>
<th>Total System Cost</th>
<th>tpsE</th>
<th>$ USD /tpsE</th>
<th>Total Solution Availability Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM System x3850 X5</td>
<td>Microsoft SQL Server 2008 R2 Enterprise Edition</td>
<td>$645,605 USD</td>
<td>4593.17</td>
<td>$140.56 USD</td>
<td>August 26, 2011</td>
</tr>
<tr>
<td></td>
<td>Microsoft Windows Server 2008 R2 Enterprise Edition SP1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The benchmark implementation and results were audited by Doug Johnson for InfoSizing (www.sizing.com). The auditor’s attestation letter is contained in this report.
IBM® System x® 3850 X5
Microsoft® SQL Server 2008 R2

TPC-E 1.12.0
TPC Pricing 1.6.0

Report Date: August 26, 2011
Revision Date: August 26, 2011

TPC-E Throughput
4593.17 tpsE

Price/Performance
$140.56 USD per tpsE

Availability Date
August 26, 2011

Total System Cost
$645,605 USD

Database Server Configuration

Operating System
Microsoft Windows Server 2008 R2 Enterprise Edition SP1

Database Manager
Microsoft SQL Server 2008 R2 Enterprise Edition

Processors/Cores/Threads
8/80/160

Memory
2048GB

Initial Database Size
18,463 GB

Redundancy Level:
1 RAID-10 Log
1 RAID-5 Data

Storage
2 x 250GB 2.5” 7.2K SATA
143 x 200GB 2.5” SAS SSD
16 x 600GB 2.5” 10K SAS

2 x IBM x3650 M3, each with:
- 2 x Intel Xeon Processor X5650 2.66GHz
  (2 Procs/12 Cores/24 Threads)
- 8GB Memory
- 2 x 250GB SFF SATA (RAID-1)
- 1 x IBM ServeRAID M1015
- Onboard Quad Gb Ethernet

IBM System x3850 X5, with:
- 8 x Intel Xeon Processor E7-8870 2.40GHz
  (8 Procs/80 Cores/160 Threads)
- 2048GB Memory
- 2 x 250GB SFF SATA (RAID-1)
- 6 x 600GB 10K SAS (RAID-10)
- 1 x IBM ServeRAID M5015
- 11 x IBM ServeRAID M5025
- Onboard Quad Gb Ethernet
- NetXtreme Dual Gb Ethernet

11 x IBM EXP2524 JBOD Enclosures, with:
- 143 x 200GB 2.5” SAS SSD
  (11 x 13-drive RAID-5 DB data)
- 10 x 600GB 10K 2.5” SAS
  (RAID-5 60-Day space)

153 Total External Drives
### IBM System x3850 X5

**Microsoft SQL Server 2008 R2**

**Report Date:** August 26, 2011  
**Revision Date:** August 26, 2011  
**Availability Date:** August 26, 2011

<table>
<thead>
<tr>
<th>Description</th>
<th>Part Number</th>
<th>Price Source</th>
<th>Unit Price</th>
<th>Quantity</th>
<th>Extended Price</th>
<th>3-Yr. Maint. Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Server Hardware</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM System x3850 X5 Configure-To-Order, includes:</td>
<td>714MC1</td>
<td>1</td>
<td>37,643</td>
<td>2</td>
<td>75,286</td>
<td></td>
</tr>
<tr>
<td>x3850 X5/x3950 X5 Base</td>
<td>7626</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM 1979W Power Supply</td>
<td>2111</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intel Xeon Processor E7-8870 10C (2.40GHz 30MB L3 8S)</td>
<td>A14L, A14Y</td>
<td>1</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM x3850 X5 and x3950 X5 Memory Expansion Card</td>
<td>A14D</td>
<td>1</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM x3850 X5/x3950 X5 System Planar</td>
<td>A14C</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM 1975W Power Supply</td>
<td>2111</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Server Storage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM 250GB 7200 NL SATA 2.5&quot; SFF HS HDD</td>
<td>81Y9722</td>
<td>1</td>
<td>289</td>
<td>2</td>
<td>578</td>
<td></td>
</tr>
<tr>
<td>IBM 600GB 10K 6Gbps SAS 2.5&quot; SFF Slim-HS HDD</td>
<td>49Y2003</td>
<td>1</td>
<td>799</td>
<td>6</td>
<td>4,794</td>
<td></td>
</tr>
<tr>
<td><strong>Server Software</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SQL Server 2008 R2 Enterprise Edition</td>
<td>810-08527</td>
<td>2</td>
<td>23,848</td>
<td>8</td>
<td>190,784</td>
<td></td>
</tr>
<tr>
<td>Windows Server 2008 R2 Enterprise Edition</td>
<td>P72-04217</td>
<td>2</td>
<td>3,999</td>
<td>1</td>
<td>3,999</td>
<td></td>
</tr>
<tr>
<td>Microsoft Problem Resolution Services</td>
<td>N/A</td>
<td>2a</td>
<td>259</td>
<td>1</td>
<td>259</td>
<td></td>
</tr>
<tr>
<td><strong>Client Hardware</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM System x3650 M3 Configure-To-Order, includes:</td>
<td>7945AC1</td>
<td>1</td>
<td>5,532</td>
<td>2</td>
<td>11,064</td>
<td></td>
</tr>
<tr>
<td>System Common Planar for 1U/3U</td>
<td>5692</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM System x3650 M3 Base with 675W AC power supply</td>
<td>5694</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intel Xeon Processor X9650 6C 2.66GHz 12MB 1333MHz 95w</td>
<td>4589, 7709</td>
<td>2</td>
<td>1745</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM x3650 M3 8 HDD Kit</td>
<td>1745</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM x3650 M3 PCIe (8 x8 slots) Riser Card</td>
<td>3754, 5086</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM ServeRAID M1015 SAS/SATA Controller</td>
<td>0095</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM UltraSlim Enhanced SATA DVD-ROM</td>
<td>4161</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual port 1Gb Ethernet daughter card</td>
<td>3585</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM 250GB 7200 NL SATA 2.5&quot; SFF HS HDD</td>
<td>81Y9722</td>
<td>1</td>
<td>289</td>
<td>4</td>
<td>1,156</td>
<td></td>
</tr>
<tr>
<td><strong>Client Software</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microsoft Windows Server 2008 R2 Standard Edition</td>
<td>P73-04980</td>
<td>2</td>
<td>1,029</td>
<td>2</td>
<td>2,058</td>
<td></td>
</tr>
<tr>
<td>Microsoft Open Program Discount Schedule</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Infrastructure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethernet Cables (2 spares)</td>
<td>RCW-717</td>
<td>3</td>
<td></td>
<td>6</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

**TPC-E 1.12.0**  
**TPC Pricing 1.6.0**  

| **Dollar Volume Discount (See Note 1)** | 29.85% | 1 | | | | |
| **Microsoft Open Program Discount Schedule** | 20.11% | 2 | | | | |

<table>
<thead>
<tr>
<th><strong>Three-Year Cost of Ownership USD:</strong></th>
<th><strong>TPC-E Throughput:</strong></th>
<th>$140.56</th>
</tr>
</thead>
<tbody>
<tr>
<td>$645,605</td>
<td>4,593.17</td>
<td>$140.56</td>
</tr>
</tbody>
</table>

**Note**: Discounts for similarly sized configurations will be similar to what is quoted here, but may vary based on the specific components priced.  
Discounts for similarly sized configurations will be similar to what is quoted here, but may vary based on the specific components priced.  
S: One or more components of the measured configuration have been substituted in the priced configuration.  
See the FDR for details.

---

**Benchmark results and test methodology audited by Doug Johnson for InfoSizing, Inc. (www.sizing.com)**

Prices used in TPC benchmarks reflect the actual prices a customer would pay for a one-time purchase of the stated components.  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 components.  For complete details, see the pricing section of the TPC benchmark specifications.  If you find that stated prices are not available according to these terms, please inform the TPC at pricing@tpc.org. Thank you.
# IBM System x3850 X5
## Microsoft SQL Server 2008 R2

## TPC-E 1.12.0

| Report Date: | August 26, 2011 |
| Revision Date: | August 26, 2011 |
| Availability Date: | August 26, 2011 |

## Numerical Quantities Summary

<table>
<thead>
<tr>
<th>Response Time (in seconds)</th>
<th>Minimum</th>
<th>Average</th>
<th>90th Percentile</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broker-Volume</td>
<td>0.01</td>
<td>0.03</td>
<td>0.06</td>
<td>0.86</td>
</tr>
<tr>
<td>Customer-Position</td>
<td>0.01</td>
<td>0.02</td>
<td>0.04</td>
<td>4.71</td>
</tr>
<tr>
<td>Market-Feed</td>
<td>0.01</td>
<td>0.02</td>
<td>0.04</td>
<td>4.68</td>
</tr>
<tr>
<td>Market-Watch</td>
<td>0.01</td>
<td>0.03</td>
<td>0.06</td>
<td>0.62</td>
</tr>
<tr>
<td>Security-Detail</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>5.21</td>
</tr>
<tr>
<td>Trade-Lookup</td>
<td>0.01</td>
<td>0.11</td>
<td>0.19</td>
<td>2.49</td>
</tr>
<tr>
<td>Trade-Order</td>
<td>0.01</td>
<td>0.05</td>
<td>0.08</td>
<td>4.92</td>
</tr>
<tr>
<td>Trade-Result</td>
<td>0.01</td>
<td>0.06</td>
<td>0.10</td>
<td>4.77</td>
</tr>
<tr>
<td>Trade-Status</td>
<td>0.01</td>
<td>0.01</td>
<td>0.03</td>
<td>1.46</td>
</tr>
<tr>
<td>Trade-Update</td>
<td>0.01</td>
<td>0.13</td>
<td>0.20</td>
<td>4.94</td>
</tr>
<tr>
<td>Data-Maintenance</td>
<td>0.01</td>
<td>0.03</td>
<td>N/A</td>
<td>0.45</td>
</tr>
</tbody>
</table>

## Transaction Mix

<table>
<thead>
<tr>
<th>Transaction</th>
<th>Transaction Count</th>
<th>Mix %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broker-Volume</td>
<td>16,204,137</td>
<td>4.900%</td>
</tr>
<tr>
<td>Customer-Position</td>
<td>42,991,371</td>
<td>13.000%</td>
</tr>
<tr>
<td>Market-Feed</td>
<td>3,307,089</td>
<td>1.000%</td>
</tr>
<tr>
<td>Market-Watch</td>
<td>59,526,259</td>
<td>18.000%</td>
</tr>
<tr>
<td>Security-Detail</td>
<td>46,297,562</td>
<td>14.000%</td>
</tr>
<tr>
<td>Trade-Lookup</td>
<td>26,455,841</td>
<td>8.000%</td>
</tr>
<tr>
<td>Trade-Order</td>
<td>33,401,097</td>
<td>10.100%</td>
</tr>
<tr>
<td>Trade-Result</td>
<td>33,070,834</td>
<td>10.000%</td>
</tr>
<tr>
<td>Trade-Status</td>
<td>62,833,356</td>
<td>19.000%</td>
</tr>
<tr>
<td>Trade-Update</td>
<td>6,613,983</td>
<td>2.000%</td>
</tr>
<tr>
<td>Data-Maintenance</td>
<td>120</td>
<td>N/A</td>
</tr>
</tbody>
</table>

## Test Duration and Timings

<table>
<thead>
<tr>
<th>Test Duration and Timings</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramp-up Time (hh:mm:ss)</td>
<td>00:40:59</td>
</tr>
<tr>
<td>Measurement Interval (hh:mm:ss)</td>
<td>02:00:00</td>
</tr>
<tr>
<td>Business Recovery Time (hh:mm:ss)</td>
<td>02:02:23</td>
</tr>
<tr>
<td>Total Number of Transactions Completed in Measurement Interval</td>
<td>330,701,529</td>
</tr>
</tbody>
</table>
# Table of Contents

Abstract ......................................................................................................................... 3

Table of Contents ......................................................................................................... 7

Clause 0 – Preamble ...................................................................................................... 9

Clause 1 – Introduction ................................................................................................. 11
  Benchmark Sponsor ..................................................................................................... 11
  Configuration Diagrams ............................................................................................. 11
  Measured and Priced Configurations ......................................................................... 11
  Figure 1-1. Measured Configuration ......................................................................... 11
  Hardware and Software Configuration Steps ........................................................... 12

Clause 2 – Database Design, Scaling, and Population .................................................. 13
  Database Creation and Table Definitions ................................................................ 13
  Database Physical Organization ................................................................................ 13
  Horizontal/Vertical Partitioning ............................................................................... 14
  Replication ............................................................................................................... 14
  Table Attributes ...................................................................................................... 14
  Cardinality of Tables ............................................................................................... 14
  Table 2-1. Initial Cardinality of Tables .................................................................... 15
  Distribution of Tables and Logs ............................................................................... 16
  Table 2-2. Data Distribution for the Measured and Priced Configuration ............... 16
  Database Interface and Model Implemented ........................................................... 18
  Database Load Methodology .................................................................................. 18

Clause 3 – Transaction Related Items ......................................................................... 19
  Vendor-Supplied Code ............................................................................................. 19
  Database Footprint of Transactions ........................................................................ 19

Clause 4 – SUT, Driver, and Network .......................................................................... 20
  Network Configuration ............................................................................................. 20

Clause 5 – EGen .......................................................................................................... 21
  EGen Version .......................................................................................................... 21
  EGen Code and Modifications ............................................................................... 21
  EGen Files .............................................................................................................. 21

Clause 6 – Performance Metrics and Response Time .................................................. 22
  EGen Instances ...................................................................................................... 22
  Measured Throughput ............................................................................................ 22
  Throughput vs. Elapsed Time for Trade-Result Transaction .................................... 22
  Figure 6-1. Test Run Graph ................................................................................... 22
  Steady State Methodology .................................................................................... 23
  Work Performed During Steady State ................................................................... 23
  Transaction Statistics ............................................................................................ 23
  Table 6-1. Transaction Statistics ........................................................................... 24

Clause 7 – Transaction and System Properties ............................................................. 25
  Atomicity Requirements ......................................................................................... 25
  Consistency Requirements ...................................................................................... 25
  Isolation Requirements ........................................................................................... 26
  Durability Requirements ........................................................................................ 26
  Durability Test for Data Accessibility ................................................................... 26
  Figure 7-1. Data Accessibility Graph ..................................................................... 27
  Durability Test for Business Recovery ................................................................... 27
  Figure 7-2. Business Recovery Time Graph ......................................................... 29
Clause 0 – Preamble

Introduction

TPC Benchmark™ E (TPC-E) is an On-Line Transaction Processing (OLTP) workload. It is a mixture of read-only and update intensive transactions that simulate the activities found in complex OLTP application environments. The database schema, data population, transactions, and implementation rules have been designed to be broadly representative of modern OLTP systems. The benchmark exercises a breadth of system components associated with such environments, which are characterized by:

- The simultaneous execution of multiple transaction types that span a breadth of complexity
- Moderate system and application execution time
- A balanced mixture of disk input/output and processor usage
- Transaction integrity (ACID properties)
- A mixture of uniform and non-uniform data access through primary and secondary keys
- Databases consisting of many tables with a wide variety of sizes, attributes, and relationships with realistic content
- Contention on data access and update

The TPC-E operations are modeled as follows: The database is continuously available 24 hours a day, 7 days a week, for data processing from multiple sessions and data modifications against all tables, except possibly during infrequent (e.g., once a month) maintenance sessions. Due to the worldwide nature of the application modeled by the TPC-E benchmark, any of the transactions may be executed against the database at anytime, especially in relation to each other.

Goal of the TPC-E Benchmark

The TPC-E benchmark simulates the OLTP workload of a brokerage firm. The focus of the benchmark is the central database that executes transactions related to the firm’s customer accounts. In keeping with the goal of measuring the performance characteristics of the database system, the benchmark does not attempt to measure the complex flow of data between multiple application systems that would exist in a real environment.

The mixture and variety of transactions being executed on the benchmark system is designed to capture the characteristic components of a complex system. Different transaction types are defined to simulate the interactions of the firm with its customers as well as its business partners. Different transaction types have varying run-time requirements.

The benchmark defines:

- Two types of transactions to simulate Consumer-to-Business as well as Business-to-Business activities
- Several transactions for each transaction type
- Different execution profiles for each transaction type
- A specific run-time mix for all defined transactions

For example, the database will simultaneously execute transactions generated by systems that interact with customers along with transactions that are generated by systems that interact with financial markets as well as administrative systems. The benchmark system will interact with a set of driver systems that simulate the various sources of transactions without requiring the benchmark to implement the complex environment.

The performance metric reported by TPC-E is a “business throughput” measure of the number of completed Trade-Result transactions processed per second. Multiple transactions are used to simulate the business activity of processing a trade, and each transaction is subject to a response time constraint. The performance metric for the benchmark is expressed in transactions-per-second-E (tpsE). To be compliant with the TPC-E standard, all references to tpsE results must include the tpsE rate, the associated price-per-tpsE, and the availability date of the priced configuration.
TPC-E uses terminology and metrics that are similar to other benchmarks, originated by the TPC and others. Such similarity in terminology does not imply that TPC-E results are comparable to other benchmarks. The only benchmark results comparable to TPC-E are other TPC-E results that conform to a comparable version of the TPC-E specification.

**Restrictions and Limitations**

Despite the fact that this benchmark offers a rich environment that represents many OLTP applications, this benchmark does not reflect the entire range of OLTP requirements. In addition, the extent to which a customer can achieve the results reported by a vendor is highly dependent on how closely TPC-E approximates the customer application. The relative performance of systems derived from this benchmark does not necessarily hold for other workloads or environments. Extrapolations to any other environment are not recommended.

Benchmark results are highly dependent upon workload, specific application requirements, and systems design and implementation. Relative system performance will vary because of these and other factors. Therefore, TPC-E should not be used as a substitute for specific customer application benchmarking when critical capacity planning and/or product evaluation decisions are contemplated.
Clause 1 – Introduction

Benchmark Sponsor

A statement identifying the benchmark Sponsor(s) and other participating companies must be reported.

This benchmark was sponsored by IBM Corporation.

Configuration Diagrams

Diagrams of both the Measured and Priced Configurations must be reported, accompanied by a description of the differences.

Any information and/or measurement results used to prove the validity of a Component substitution must be included in the FDR. Original and substituted Components must be clearly identified. Proof of comparable performance for substitution without a full benchmark run must be cited in the FDR.

Measured and Priced Configurations

The measured configuration is shown in Figure 1-1. The priced configuration is shown above in the executive summary.

Figure 1-1. Measured Configuration

2 x IBM x3650 M3, each with:
- 2 x Intel Xeon Processor X5650 2.66GHz
- 8GB Memory
- 2 x 250GB SFF SATA (RAID-1)
- 1 x IBM ServeRAID M1015
- Onboard Quad Gb Ethernet

IBM System x3850 X5, with:
- 8 x Intel Xeon Processor E7-8870 2.40GHz
- 2048GB Memory
- 2 x 250GB SFF SATA (RAID-1)
- 6 x 600GB 10K SAS (RAID-10)
- 1 x IBM ServeRAID M5015
- 11 x IBM ServeRAID M5025
- Onboard Quad Gb Ethernet
- NetXtreme Dual Gb Ethernet

16 x IBM EXP2524 JBOD Enclosures, with:
- 143 x 200GB 2.5” SAS SSD (11 x 13-drive RAID-5 DB data)
- 10 x 600GB 10K 2.5” SAS (RAID-5 60-Day space)
- 120 x 600GB 2.5” SAS HDD (5 x 24-drive RAID-10 backup and temp space)

273 Total External Drives
Compared to the priced configuration, the measured configuration contained extra external enclosures and drives used strictly for database backup files and temporary space used during the benchmark database load process. These extra enclosures and drives were not used at all during the benchmark runs.

**Hardware and Software Configuration Steps**

A description of the steps taken to configure all the hardware must be reported in the Report.

A description of the steps taken to configure all the software must be reported in the Report. Any and all configuration scripts or step by step GUI instructions are reported in the Supporting Files (see Clauses 9.4.1.1 and 9.4.1.2). The description, scripts and GUI instructions must be sufficient such that a reader knowledgeable of computer systems and the TPC-E specification could recreate the hardware and software environments.

Detailed instructions for installing and configuring the SUT hardware and software are included in the supporting files:

- Information specific to the Tier A clients can be found in: `SupportingFiles\Introduction\TierA\TierA_x3650M3_Setup.pdf`
- Information specific to the Tier B database server and storage can be found in: `SupportingFiles\Introduction\TierB\TierB_x3850X5_Setup.pdf`
Clause 2- Database Design, Scaling, and Population

Database Creation and Table Definitions

A description of the steps taken to create the database for the Reported Throughput must be reported in the Report. Any and all scripts or step by step GUI instructions are reported in the Supporting Files (see Clause 9.4.2). The description, scripts and GUI instructions must be sufficient such that a reader knowledgeable of database software environments and the TPC-E specification could recreate the database.

The database was created and populated using the Microsoft TPC-E benchmark kit. Instructions for doing so are included in the supporting files. See SupportingFiles\Clause2\MSTPCE Database Setup Reference.pdf.

Changes and customizations were made to some of the kit files. First, the filegroups the database was loaded onto were changed in number from three filegroups to two. Second, several scripts were modified to customize the load to the specific hardware configuration of this SUT.

The default kit files create the database on three filegroups: fixed_fg, scaling_fg, and growing_fg. That was changed so that only two filegroups were used, fixed_fg and growing_fg. All of the items that would have been loaded onto scaling_fg were loaded instead onto fixed_fg.

The modified files are included as part of SupportingFiles\Clause2:

- Utility\Create_TID_Ranges_Table.sql
- DDL\ Create_Indexes_Scaling_Tables.sql
- DDL\ Create_Tables_Scaling.sql
- DDL\ Create_Tables_Scaling_Flat.sql

The files that were customized for this specific SUT hardware are included in the folder SupportingFiles\Clause2\2300000.Cust\Database:

- Tempdb.sql creates a larger temporary database for SQL Server
- Shrinktempdb.sql shrinks it back down
- Backupdev.sql creates devices for SQL Server to backup the database to
- Dropbackupdev.sql removes those devices
- Backup_Database.sql backs up the tpce database to the specified device names
- Restore_Database.sql restores the tpce database from the specified device names
- Create_Database.sql maps the database filegroups and log to physical storage
- Flatfile.txt tells the database loader where to store the database flatfiles during the load
- Remove_Database.sql drops the current tpce database

Database Physical Organization

The physical organization of tables and User-Defined Objects, within the database, must be reported in the Report.

The following tables and related indexes were on the growing_fg filegroup:

- CASH_TRANSACTION
- SETTLEMENT
- TRADE
- TRADE_HISTORY
- TRADE_REQUEST
- HOLDING
- HOLDING_HISTORY
- HOLDING_SUMMARY
The remaining tables and their related indexes were all on the fixed_fg filegroup.

**Horizontal/Vertical Partitioning**

*While few restrictions are placed upon horizontal or vertical partitioning of tables and rows in the TPC-E benchmark (see Clause 2.3.3), any such partitioning must be reported.*

Partitioning was not used for this benchmark.

**Replication**

*Replication of tables, if used, must be reported in the Report.*

Replication was not used for this benchmark.

**Table Attributes**

*Additional and/or duplicated columns in any table must be reported in the Report along with a statement on the impact on performance (see Clause 2.3.5).*

No additional attributes were used for this benchmark.

**Cardinality of Tables**

*The cardinality (e.g., the number of rows) of each table, as it existed after the database load (see Clause 2.6), must be reported in the Report.*

The database was built with 2,300,000 customers. The cardinality is shown in Table 2-1.
### Table 2-1. Initial Cardinality of Tables

<table>
<thead>
<tr>
<th>Table Name</th>
<th>Rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCOUNT_PERMISSION</td>
<td>16,329,925</td>
</tr>
<tr>
<td>ADDRESS</td>
<td>3,450,004</td>
</tr>
<tr>
<td>BROKER</td>
<td>23,000</td>
</tr>
<tr>
<td>CASH_TRANSACTION</td>
<td>36,564,513,307</td>
</tr>
<tr>
<td>CHARGE</td>
<td>15</td>
</tr>
<tr>
<td>COMMISSION_RATE</td>
<td>240</td>
</tr>
<tr>
<td>COMPANY</td>
<td>1,150,000</td>
</tr>
<tr>
<td>COMPANY_COMPETITOR</td>
<td>3,450,000</td>
</tr>
<tr>
<td>CUSTOMER</td>
<td>2,300,000</td>
</tr>
<tr>
<td>CUSTOMER_ACCOUNT</td>
<td>11,500,000</td>
</tr>
<tr>
<td>CUSTOMER_TAXRATE</td>
<td>4,600,000</td>
</tr>
<tr>
<td>DAILY_MARKET</td>
<td>2,056,027,500</td>
</tr>
<tr>
<td>EXCHANGE</td>
<td>4</td>
</tr>
<tr>
<td>FINANCIAL</td>
<td>23,000,000</td>
</tr>
<tr>
<td>HOLDING</td>
<td>2,034,872,962</td>
</tr>
<tr>
<td>HOLDING_HISTORY</td>
<td>53,263,633,646</td>
</tr>
<tr>
<td>HOLDING_SUMMARY</td>
<td>114,384,081</td>
</tr>
<tr>
<td>INDUSTRY</td>
<td>102</td>
</tr>
<tr>
<td>LAST_TRADE</td>
<td>1,575,500</td>
</tr>
<tr>
<td>NEWS_ITEM</td>
<td>2,300,000</td>
</tr>
<tr>
<td>NEWS_XREF</td>
<td>2,300,000</td>
</tr>
<tr>
<td>SECTOR</td>
<td>12</td>
</tr>
<tr>
<td>SECURITY</td>
<td>1,575,500</td>
</tr>
<tr>
<td>SETTLEMENT</td>
<td>39,744,000,000</td>
</tr>
<tr>
<td>STATUS_TYPE</td>
<td>5</td>
</tr>
<tr>
<td>TAXRATE</td>
<td>320</td>
</tr>
<tr>
<td>TRADE</td>
<td>39,744,000,000</td>
</tr>
<tr>
<td>TRADE_HISTORY</td>
<td>95,385,530,702</td>
</tr>
<tr>
<td>TRADE_REQUEST</td>
<td>0</td>
</tr>
<tr>
<td>TRADE_TYPE</td>
<td>5</td>
</tr>
<tr>
<td>WATCH_ITEM</td>
<td>229,983,863</td>
</tr>
<tr>
<td>WATCH_LIST</td>
<td>2,300,000</td>
</tr>
<tr>
<td>ZIP_CODE</td>
<td>14,741</td>
</tr>
</tbody>
</table>
Distribution of Tables and Logs

The distribution of tables, partitions and logs across all media must be explicitly depicted for the Measured and Priced Configurations.

There were two 250GB 2.5” SFF 7.2K SATA drives in the database server accessed by the internal ServeRAID M5015 SAS/SATA controller. The OS was loaded onto a RAID-1 array located on these two drives.

The database log was stored on a RAID-10 array located on six 600GB 2.5” 10K SAS drives. These drives were in the database server and were accessed by the internal ServeRAID M5015 SAS/SATA controller.

The database data was stored on external SAS SSD storage. This storage was accessed by eleven IBM ServeRAID M5025 SAS/SATA controllers. Each of these controllers was connected to one external IBM System Storage® EXP2524 6Gbps SAS JBOD enclosure, each holding thirteen 200GB SAS SSDs. In total, for database data, eleven enclosures and 143 external SSDs were connected to the database server. Eleven data arrays were each configured as 13-drive RAID-5. Each data array was broken into two partitions: one for fixed_fg (RAW) and one for growing_fg (RAW).

Additionally, one of those eleven enclosures contained ten 600GB 2.5” 10K SAS drives. These drives were configured as a RAID-5 array and formatted as NTFS. This storage space was added to meet the 60-Day space requirement.

In addition to the priced configuration described above, the measured configuration included five additional external 6Gbps SAS JBOD enclosures, each filled with twenty-four 600GB SAS HDDs. This space was used to generate and load the TPC-E benchmark database, and during database backup and restore operations. This hardware performed no function during benchmark runs. These additional five enclosures were attached, one each, to five of the eleven priced enclosures. Five 24-drive RAID-10 arrays were created using this hardware and formatted as NTFS.

Adapter write caching was disabled for all controllers and arrays.

Further details on the storage configuration are available in the supporting files. See the files in the directory SupportingFiles\Introduction\TierB.

Table 2-2 depicts the database configuration of the measured and priced systems to meet the 8-hour steady state requirement.

Table 2-2. Data Distribution for the Measured and Priced Configuration

<table>
<thead>
<tr>
<th>Disk #</th>
<th>Controller</th>
<th>Drives Enclosure RAID level</th>
<th>Partition (File System)</th>
<th>Size</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Internal M5015</td>
<td>2x250GB SATA HDD RAID-1</td>
<td>C: (NTFS)</td>
<td>231.67GB</td>
<td>OS</td>
</tr>
<tr>
<td>1</td>
<td>Internal M5015</td>
<td>6x600GB SAS HDD RAID-10</td>
<td>E: (RAW) F: (NTFS)</td>
<td>1464.84GB</td>
<td>LOG and MDF</td>
</tr>
<tr>
<td>2</td>
<td>M5025 #1</td>
<td>24x600GB SAS HDD EXP2524 RAID-5 (Measured)</td>
<td>c:\mp\bk1 (NTFS)</td>
<td>6694.21 GB</td>
<td>Backup, flatfiles, &amp; tempDB</td>
</tr>
<tr>
<td>3</td>
<td>M5025 #1</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx1 (RAW) c:\mp\gw1 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
<tr>
<td>4</td>
<td>M5025 #2</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx2 (RAW) c:\mp\gw2 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
<tr>
<td>Disk #</td>
<td>Controller</td>
<td>Drives Enclosure RAID level</td>
<td>Partition (File System)</td>
<td>Size</td>
<td>Use</td>
</tr>
<tr>
<td>--------</td>
<td>------------</td>
<td>----------------------------</td>
<td>-------------------------</td>
<td>------</td>
<td>-----</td>
</tr>
<tr>
<td>5</td>
<td>M5025 #2</td>
<td>24x600GB SAS HDD EXP2524 RAID-10 (Measured)</td>
<td>c:\mp\bk2 (NTFS)</td>
<td>6694.21 GB</td>
<td>Backup, flatfiles, &amp; tempDB</td>
</tr>
<tr>
<td>6</td>
<td>M5025 #3</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx3 (RAW) c:\mp\gw3 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
<tr>
<td>7</td>
<td>M5025 #3</td>
<td>24x600GB SAS HDD EXP2524 RAID-10 (Measured)</td>
<td>c:\mp\bk4 (NTFS)</td>
<td>6694.21 GB</td>
<td>Backup, flatfiles, &amp; tempDB</td>
</tr>
<tr>
<td>8</td>
<td>M5025 #3</td>
<td>10x600GB SAS HDD EXP2524 RAID-5</td>
<td>S: (NTFS)</td>
<td>5020.63GB</td>
<td>60-Day Space</td>
</tr>
<tr>
<td>9</td>
<td>M5025 #4</td>
<td>24x600GB SAS HDD EXP2524 RAID-10 (Measured)</td>
<td>c:\mp\bk5 (NTFS)</td>
<td>6694.21 GB</td>
<td>Backup, flatfiles, &amp; tempDB</td>
</tr>
<tr>
<td>10</td>
<td>M5025 #4</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx4 (RAW) c:\mp\gw4 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
<tr>
<td>11</td>
<td>M5025 #5</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx5 (RAW) c:\mp\gw5 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
<tr>
<td>12</td>
<td>M5025 #6</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx6 (RAW) c:\mp\gw6 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
<tr>
<td>13</td>
<td>M5025 #7</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx7 (RAW) c:\mp\gw7 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
<tr>
<td>14</td>
<td>M5025 #8</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx8 (RAW) c:\mp\gw8 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
<tr>
<td>15</td>
<td>M5025 #8</td>
<td>24x600GB SAS HDD EXP2524 RAID-10 (Measured)</td>
<td>c:\mp\bk3 (NTFS)</td>
<td>6694.21 GB</td>
<td>Backup, flatfiles, &amp; tempDB</td>
</tr>
<tr>
<td>16</td>
<td>M5025 #9</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx9 (RAW) c:\mp\gw9 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
<tr>
<td>17</td>
<td>M5025 #10</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx10 (RAW) c:\mp\gw10 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
<tr>
<td>18</td>
<td>M5025 #11</td>
<td>13x200GB SAS SSD EXP2524 RAID-5</td>
<td>c:\mp\fx11 (RAW) c:\mp\gw11 (RAW)</td>
<td>45.12GB 2178.75GB</td>
<td>Fixed_fg growing_fg</td>
</tr>
</tbody>
</table>
Database Interface and Model Implemented

A statement must be provided in the Report that describes:

- The Database Interface (e.g., embedded, call level) and access language (e.g., SQL, COBOL read/write) used to implement the TPC-E Transactions. If more than one interface / access language is used to implement TPC-E, each interface / access language must be described and a list of which interface /access language is used with which Transaction type must be reported.
- The data model implemented by the DBMS (e.g., relational, network, hierarchical).

Microsoft SQL Server 2008 R2 Enterprise Edition is a relational database. The interface used was Microsoft SQL Server stored procedures accessed with Remote Procedure Calls embedded in C++ code using the Microsoft ODBC interface.

Database Load Methodology

The methodology used to load the database must be reported in the Report.

The database was loaded using the flat files option on the EGenLoader command line. This will generate flat files first, then bulk insert the data into the tables. A further description is provided in SupportingFiles\Clause2\MSTPCE Database Setup Reference.pdf.
Clause 3 – Transaction Related Items

Vendor-Supplied Code

A statement that vendor-supplied code is functionally equivalent to Pseudo-code in the specification (see Clause 3.2.1.6) must be reported.

The stored procedure code for the transactions was functionally equivalent to the pseudo-code. The stored procedures can be seen in SupportingFiles\Clause3\StoredProcedures.

The code to interface the stored procedures can be found in:

- SupportingFiles\Clause3\BaseServer
- SupportingFiles\Clause3\TransactionsSP
- SupportingFiles\Clause3\TxnHarness

Database Footprint of Transactions

A statement that the database footprint requirements (as described in Clause 3.3) were met must be reported.

The database footprint requirements were met.
Network Configuration

The Network configurations of both the Measured and Priced Configurations must be described and reported. This includes the mandatory Network between the Driver and Tier A (see Clause 4.2.2) and any optional Database Server interface networks (see Clause 4.1.3.12).

The network configurations of the measured and priced configurations were the same. Refer to Figure 1-1 for a diagram of the network connections.

The Tier A clients and Tier B database server were connected by four Gb Ethernet crossover cables. These cables were connected to onboard Gb Ethernet ports in the clients and a combination of onboard and add-in Gb Ethernet ports in the server. These crossover networks handled all of the network traffic between Tier A and Tier B while a measurement was underway.

Another network connected the driver, the database server, the clients, and a time server. This network, which was connected via a gigabit Ethernet switch, used one of the onboard Ethernet ports on the clients and database server. This network fulfills the mandatory network between the driver and Tier A. It also allows the driver, clients, and database server to synchronize and verify their times with the time server.
Clause 5 – EGen

EGen Version

The version of EGen used in the benchmark must be reported (see Clause 5.3.1).

EGen v1.12.0 was used in the benchmark.

EGen Code and Modifications

A statement that all required TPC-provided EGen code was used in the benchmark must be reported. If the Test Sponsor modified EGen, a statement EGen has been modified must be reported in the Report. All formal waivers from the TPC documenting the allowed changes to EGen must also be reported (see Clause 5.3.7.1). If any of the changes to EGen do not have a formal waiver, that must also be reported. If the Test Sponsor extended EGenLoader, the use of the extended EGenLoader and the audit of the extension code by an Auditor must be reported (see Clause 5.7.4).

All required TPC-provided EGen code was used in the benchmark.

EGen was not modified for use in this benchmark.

EGenLoader was not extended for this benchmark.

EGen Files

The make/project files used to compile/link EGenLoader and EGenValidate must be reported in the Supporting Files. The compiler/linker options and flags used to compile/link EGen objects for the SUT must be reported in the Supporting Files.

See the supporting files directory SupportingFiles\Clause3\prj for the files related to EGenLoader and EGenValidate.

See the supporting files directory SupportingFiles\Clause3\SUT_CE_Server for the files related to the SUT_CE_Server.

See the supporting files directory SupportingFiles\Clause3\SUT_MEE_Server for the files related to the SUT_MEE_Server.
Clause 6 – Performance Metrics and Response Time

EGen Instances

The number of EGenDriverMEE and EGenDriverCE instances used in the benchmark must be reported (see Clause 6.2.5).

There were 20 EGenDriverCEs with a total of 1365 EGenDriverCE instances used in the benchmark.

There were 20 EGenDriverMEEs with a dynamic number of instances used in the benchmark.

Measured Throughput

The Measured Throughput must be reported (see Clause 6.7.1.2).

The Measured Throughput was 4593.17 tpsE.

Throughput vs. Elapsed Time for Trade-Result Transaction

A Test Run Graph of throughput versus elapsed wall clock time must be reported for the Trade-Result Transaction (see Clause 6.7.2).

Figure 6-1. Test Run Graph
Steady State Methodology

The method used to determine that the SUT had reached a Steady State prior to commencing the Measurement Interval must be reported.

During the run, observation of the tpsE as the benchmark ran was used to determine Steady State. After the run, Steady State was confirmed by:

1. Looking at the Test Run Graph and verifying that tpsE was steady prior to commencing the Measurement Interval.
2. Calculating the average tpsE over 60-minute windows during Steady State, with the start of each window 10 minutes apart. Then it was confirmed that the minimum 60-minute average tpsE was not less than 98% of the Reported Throughput, and that the maximum 60-minute average tpsE was not greater than 102% of the Reported Throughput.
3. Calculating the average tpsE over 10-minute windows during Steady State, with the start of each window 1 minute apart. Then it was confirmed that the minimum 10-minute average tpsE was not less than 80% of the Reported Throughput, and the maximum 10-minute average tpsE was not greater than 120% of the Reported Throughput.

Work Performed During Steady State

A description of how the work normally performed during a Test Run, actually occurred during the Measurement Interval must be reported (e.g., checkpointing, writing Undo/Redo Log records).

Checkpoints had a duration of 430 seconds and were scheduled to run every 447 seconds.

Data-Maintenance was run every 60 seconds.

Transaction Statistics

The recorded averages over the Measurement Interval for each of the Transaction input parameters specified by clause 6.4.1 must be reported.

Table 6-1 contains the transaction statistics.
Table 6-1. Transaction Statistics

<table>
<thead>
<tr>
<th>Input Parameter</th>
<th>Value</th>
<th>Actual Percentage</th>
<th>Required Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Customer-Position</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By Tax ID</td>
<td>1</td>
<td>50.01%</td>
<td>48% to 52%</td>
</tr>
<tr>
<td>Get History</td>
<td>1</td>
<td>49.98%</td>
<td>48% to 52%</td>
</tr>
<tr>
<td><strong>Market-Watch</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Securities Chosen By</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watch List</td>
<td></td>
<td>60.00%</td>
<td>57% to 63%</td>
</tr>
<tr>
<td>Account ID</td>
<td></td>
<td>35.00%</td>
<td>33% to 37%</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td>5.00%</td>
<td>4.5% to 5.5%</td>
</tr>
<tr>
<td><strong>Security-Detail</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access LOB</td>
<td>1</td>
<td>1.00%</td>
<td>0.9% to 1.1%</td>
</tr>
<tr>
<td><strong>Trade-Lookup</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame to Execute</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>30.01%</td>
<td>28.5% to 31.5%</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>29.99%</td>
<td>28.5% to 31.5%</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>30.00%</td>
<td>28.5% to 31.5%</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>10.00%</td>
<td>9.5% to 10.5%</td>
</tr>
<tr>
<td><strong>Trade-Order</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transactions Requested by a Third Party</td>
<td>10.00%</td>
<td>9.5% to 10.5%</td>
<td></td>
</tr>
<tr>
<td>By Company Name</td>
<td></td>
<td>40.00%</td>
<td>38% to 42%</td>
</tr>
<tr>
<td>Buy On Margin</td>
<td>1</td>
<td>8.00%</td>
<td>7.5% to 8.5%</td>
</tr>
<tr>
<td>Rollback</td>
<td>1</td>
<td>0.99%</td>
<td>0.94% to 1.04%</td>
</tr>
<tr>
<td>LIFO</td>
<td>1</td>
<td>35.00%</td>
<td>33% to 37%</td>
</tr>
<tr>
<td><strong>Trade Quantity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>25.01%</td>
<td>24% to 26%</td>
</tr>
<tr>
<td>200</td>
<td>200</td>
<td>25.00%</td>
<td>24% to 26%</td>
</tr>
<tr>
<td>400</td>
<td>400</td>
<td>24.99%</td>
<td>24% to 26%</td>
</tr>
<tr>
<td>800</td>
<td>800</td>
<td>25.00%</td>
<td>24% to 26%</td>
</tr>
<tr>
<td><strong>Trade Type</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market Buy</td>
<td></td>
<td>30.00%</td>
<td>29.7% to 30.3%</td>
</tr>
<tr>
<td>Market Sell</td>
<td></td>
<td>30.00%</td>
<td>29.7% to 30.3%</td>
</tr>
<tr>
<td>Limit Buy</td>
<td></td>
<td>20.00%</td>
<td>19.8% to 20.2%</td>
</tr>
<tr>
<td>Limit Sell</td>
<td></td>
<td>9.99%</td>
<td>9.9% to 10.1%</td>
</tr>
<tr>
<td>Stop Loss</td>
<td></td>
<td>10.00%</td>
<td>9.9% to 10.1%</td>
</tr>
<tr>
<td><strong>Trade-Update</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame to Execute</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>33.01%</td>
<td>31% to 35%</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>33.00%</td>
<td>31% to 35%</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>33.99%</td>
<td>32% to 36%</td>
</tr>
</tbody>
</table>
Clause 7 – Transaction and System Properties

The ACID (Atomicity, Consistency, Isolation, and Durability) properties of transaction processing systems must be supported by the System Under Test during the running of this benchmark. It is the intent of this section to define the ACID properties informally and to specify a series of tests that must be performed to demonstrate that these properties are met.

The results of the ACID tests must be reported in the Report along with a description of how the ACID requirements were met, and how the ACID tests were run.

Atomicity Requirements

The System Under Test must guarantee that Database Transactions are atomic; the system will either perform all individual operations on the data, or will ensure that no partially completed operations leave any effects on the data.

All ACID tests were conducted according to specification. The following steps were performed to verify the Atomicity of the Trade-Order transactions:

- Perform a market Trade-Order Transaction with the roll_it_back flag set to false. Verify that the appropriate rows have been inserted in the TRADE and TRADE_HISTORY tables.
- Perform a market Trade-Order Transaction with the roll_it_back flag set to true. Verify that no rows associated with the rolled back Trade-Order have been added to the TRADE and TRADE_HISTORY tables.

The procedure for running the atomicity tests is documented in the file SupportingFiles\Clause7\MSTPCE ACID Procedures.pdf.

The atomicity scripts and outputs are located in the directory SupportingFiles\Clause7\Atomicity.

Consistency Requirements

Consistency is the property of the Application that requires any execution of a Database Transaction to take the database from one consistent state to another. A TPC-E database when first populated by EGenLoader must meet these consistency conditions. The three consistency conditions must be tested after initial database population and after any Business Recovery tests.

Consistency condition 1:
Entries in the BROKER and TRADE tables must satisfy the relationship:
B_NUM_TRADES = count(*)
For each broker defined by:
(B_ID = CA_B_ID) and (CA_ID = T_CA_ID) and (T_ST_ID = CMPT').

Consistency condition 2:
Entries in the BROKER and TRADE tables must satisfy the relationship:
B_COMM_TOTAL = sum(T_COMM)
For each broker defined by:
(B_ID = CA_B_ID) and (CA_ID = T_CA_ID) and (T_ST_ID = CMPT').

Consistency condition 3:
Entries in the HOLDING_SUMMARY and HOLDING tables must satisfy the relationship:
HS_QTY = sum(H_QTY)
For each holding summary defined by:
(HS_CA_ID = H_CA_ID) and (HS_S_SYMB = H_S_SYMB).
Consistency conditions 1, 2, and 3 were tested using a batch file to issue queries to the database after the database was loaded and after the Business Recovery Test. The results of the queries demonstrated that the database was consistent for all three tests.

The procedure for running the consistency tests is documented in the file SupportingFiles\Clause7\MSTPCE ACID Procedures.pdf.

The consistency scripts and outputs are located in the directory SupportingFiles\Clause7\Consistency.

Isolation Requirements

The isolation property of a Transaction is the level to which it is isolated from the actions of other concurrently executing Transactions. Systems that implement Transaction isolation using a locking and/or versioning scheme must demonstrate compliance with the isolation requirements by executing the tests described in Clause 7.4.2.

Isolation tests 1 through 4 were successfully done following the procedure documented in the file SupportingFiles\Clause7\MSTPCE ACID Procedures.pdf.

The isolation scripts and outputs are located in the directory SupportingFiles\Clause7\Isolation.

Durability Requirements

The SUT must provide Durability. In general, state that persists across failures is said to be Durable and an implementation that ensures state persists across failures is said to provide Durability. In the context of the benchmark, Durability is more tightly defined as the SUT’s ability to ensure all Committed data persist across a Single Point of Failure.

Durability Test for Data Accessibility

The Test Sponsor must report in the Report the Redundancy Level (see Clause 7.6.7.1) and describe the Data Accessibility test(s) used to demonstrate compliance.

A Data Accessibility Graph for each run demonstrating a Redundancy Level must be reported in the Report (see Clause 7.6.7.2).

This benchmark result used Redundancy Level 1. The test for Redundancy Level 1 is the test for permanent irrecoverable failure of any single Durable Medium.

To prove Redundancy Level 1, the following steps were successfully performed:

1. Performed Trade-Cleanup to remove remnants of previous benchmark runs from the database.
2. Determined the current number of completed trades in the database, count1.
3. Started a run, using the profile from the measured run, with checkpoints, and met the Durability Throughput Requirements for at least 5 minutes.
4. Induced the first failure, which in this case was failing a drive in the database log array by physically removing it from its enclosure. Since the database log array is RAID protected, transaction processing continued.
5. Waited until the Durability Throughput Requirements were met again for at least 5 minutes.
6. Induced the second failure, which in this case was failing a drive in a database data array by physically removing it from its enclosure. Since the database data arrays are RAID protected, transaction processing continued.
7. After a few minutes passed, a new drive was inserted into the data enclosure to replace the failed data drive. The data array rebuilding process was started.
8. After a few minutes passed, a new drive was inserted into the log enclosure to replace the failed log drive. The log array rebuilding process was started.

9. Continued running the benchmark for at least 20 minutes.

10. Terminated the run gracefully.

11. Retrieved the new number of completed trades in the database by running `select count(*) as count2 from SETTLEMENT`.

12. Verified that `(count2 - count1)`, which is the number of actual completed Trade-Result Transactions done during the run, equaled the number of successful Trade-Result transactions reported by the Driver.

13. Allowed the recovery process to complete.

Figure 7-1 is a graph of the measured throughput versus elapsed time for the data accessibility run. The timings of the induced failures as well as the recovery process are indicated.

**Figure 7-1. Data Accessibility Graph**

The files related to this data accessibility test are located in SupportingFiles\Clause7\Durability\DataAccessibility.

**Durability Test for Business Recovery**

*The Test Sponsor must describe in the Report the test(s) used to demonstrate Business Recovery.*

The Business Recovery Time must be reported on the Executive Summary Statement and in the Report. If the failures described in Clauses 7.6.2.2, 7.6.2.3 and 7.6.2.4 were not combined into one Durability test (usually powering off the Database Server during the run), then the Business Recovery Time for the failure described for instantaneous interruption is the Business Recovery Time that must be reported in the Executive Summary Statement. All the Business Recovery Times for each test requiring Business Recovery must be reported in the Report.
The Business Recovery Time Graph (see Clause 7.6.7.4) must be reported in the Report for all Business Recovery tests.

The tests for “Loss of processing,” “Loss of Vulnerable Storage Component,” and “Loss of all external power to the SUT” were combined.

The following steps were successfully performed to test Business Recovery:

1. Performed Trade-Cleanup to remove remnants of previous benchmark runs from the database.
2. Determined the current number of completed trades in the database, \( \text{count1} \).
3. Started a run, using the profile from the measured run, with checkpoints, and met the Durability Throughput Requirements for at least 20 minutes.
4. Pulled the power cords from the database server.
5. Stopped submitting Transactions.
6. Plugged in and restarted the database server.
7. Started SQL Server on the database server. It automatically began recovery of the tpce database. The timestamp in the SQL Server ERRORLOG of the first message related to database tpce is considered the start of Database Recovery.
8. Waited for SQL Server to finish recovering the database. The timestamp in the SQL Server ERRORLOG of the message indicating that the recovery of database tpce is complete is considered the end of Database Recovery.
9. Since there was a time gap between the end of Database Recovery and the start of Application Recovery, and the Drivers and Transactions needed to be started again (not just continued), the Trade-Cleanup Transaction was executed during this time gap.
10. Started a run, using the profile from the measured run, with checkpoints. The time when the first transaction is submitted to the database is considered the start of Application Recovery.
11. Let the run proceed until a 20 minute window existed such that the first minute of the window and the entire window both scored at least 95% of the Reported Throughput. The time of the beginning of that 20-minute window is considered the end of Application Recovery.
12. Terminated the run gracefully.
13. Verified that no errors were reported during steps 8 through 12.
14. Retrieved the new number of completed trades in the database by running
   \[
   \text{select count(*) as count2 from SETTLEMENT.}
   \]
15. Verified that \( \text{count2} - \text{count1} \), which is the number of actual completed Trade-Result Transactions done during the two runs, was greater than or equal to the combined number of successful Trade-Result Transactions reported by the Driver for both runs. In the case of an inequality, verified that the difference was less than or equal to the maximum number of transactions that could be simultaneously in-flight from the Driver to the SUT.

Figure 7-2 is a graph of the measured throughput versus elapsed time for Business Recovery.

The Database Recovery Time was 01:39:52. The Application Recovery Time was 00:22:31. The Business Recovery Time, which is the sum of the Database Recovery Time and the Application Recovery Time, was 02:02:23.
Figure 7-2. Business Recovery Time Graph

The files related to this business recovery test are located in SupportingFiles\Clause7\Durability\BusinessRecovery.
### Clause 8 – Pricing

#### 60-Day Space

Details of the 60-Day Space computations (see Clause 6.6.6.6) along with proof that the database is configured to sustain a Business Day of growth (see Clause 6.6.6.1) must be reported in the Report.

The 60-day space calculations shown in Table 8-1 are included in SupportingFiles\Clause8\tpce_space.xls.

Table 8-1. Disk Space Requirements

<table>
<thead>
<tr>
<th>Field</th>
<th>TPC-E Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company Name</td>
<td></td>
</tr>
<tr>
<td>Revenue</td>
<td>2,300,000</td>
</tr>
<tr>
<td>Performance</td>
<td>400 MB/TPC</td>
</tr>
<tr>
<td>Reported</td>
<td>400 MB/TPC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field</th>
<th>Configured Data Space (MB)</th>
<th>Data Space Configured (MB)</th>
<th>Data Size (KB)</th>
<th>MB Allocated</th>
<th>MB Loaded</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>11</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RAM</td>
<td>1,000,000</td>
<td>990,000</td>
<td>20,000,000</td>
<td>19,980,000</td>
<td>19,980,000</td>
</tr>
<tr>
<td>RAID Overhead</td>
<td>349,141</td>
<td>139,851</td>
<td>5,922</td>
<td>5,922</td>
<td>5,922</td>
</tr>
<tr>
<td>Log Growth/Trade</td>
<td>349,141</td>
<td>139,851</td>
<td>5,922</td>
<td>5,922</td>
<td>5,922</td>
</tr>
<tr>
<td>Initial Log Size</td>
<td>1,000,000</td>
<td>990,000</td>
<td>20,000,000</td>
<td>19,980,000</td>
<td>19,980,000</td>
</tr>
<tr>
<td>Log LUNS</td>
<td>1,000</td>
<td>990</td>
<td>20,000,000</td>
<td>19,980,000</td>
<td>19,980,000</td>
</tr>
<tr>
<td>Log LUNS</td>
<td>349,141</td>
<td>139,851</td>
<td>5,922</td>
<td>5,922</td>
<td>5,922</td>
</tr>
<tr>
<td>Log LUNS</td>
<td>349,141</td>
<td>139,851</td>
<td>5,922</td>
<td>5,922</td>
<td>5,922</td>
</tr>
<tr>
<td>Log LUNS</td>
<td>1,000,000</td>
<td>990,000</td>
<td>20,000,000</td>
<td>19,980,000</td>
<td>19,980,000</td>
</tr>
<tr>
<td>Log LUNS</td>
<td>349,141</td>
<td>139,851</td>
<td>5,922</td>
<td>5,922</td>
<td>5,922</td>
</tr>
<tr>
<td>Log LUNS</td>
<td>349,141</td>
<td>139,851</td>
<td>5,922</td>
<td>5,922</td>
<td>5,922</td>
</tr>
<tr>
<td>Log LUNS</td>
<td>1,000,000</td>
<td>990,000</td>
<td>20,000,000</td>
<td>19,980,000</td>
<td>19,980,000</td>
</tr>
<tr>
<td>Log LUNS</td>
<td>349,141</td>
<td>139,851</td>
<td>5,922</td>
<td>5,922</td>
<td>5,922</td>
</tr>
<tr>
<td>Log LUNS</td>
<td>349,141</td>
<td>139,851</td>
<td>5,922</td>
<td>5,922</td>
<td>5,922</td>
</tr>
</tbody>
</table>

©IBM Corporation TPC-E Benchmark Full Disclosure Report – August 2011 30
Availability Date

The committed Availability Date of Components used in the price calculations must be reported with a precision of one day. All hardware, software and support used in the calculations must be Orderable by Any Customer on the Availability Date. For each of the Components that are not Orderable on the report date of the FDR, the following information must be included in the FDR:

- Name and Part Number of the item that is not Orderable
- The date when the Component can be ordered (on or before the Availability Date)
- The method to be used to order the Component (at or below the quoted price) when the order date arrives
- The method for verifying the price

The total solution as priced will be generally available August 26, 2011.

Supporting Files Index

An index for all files required by Clause 9.4 Supporting Files must be provided.

An index of the files contained in the supporting files is here: SupportingFiles\SupportingFilesIndex.pdf

Auditor’s Attestation Letter

The Auditor’s Attestation Letter, which indicates compliance, must be included in the Report.

The auditor’s Attestation Letter is on the next two pages.
Joe Herman, Manager
System x Server Performance
IBM Systems and Technology Group
3039 Cornwallis Road
RTP, NC 27709

August 24, 2011

I verified the TPC Benchmark™ E performance of the following configuration:

Platform: IBM System x3850 X5
Operating System: Microsoft Windows Server 2008 R2 Enterprise Edition SP1
Database Manager: Microsoft SQL Server 2008 R2 Enterprise Edition

The results were:

<table>
<thead>
<tr>
<th>CPU's Speed</th>
<th>Memory</th>
<th>Disks</th>
<th>Trade-Result 90% Response Time</th>
<th>tpsE</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 x Intel Xeon E7-8870 (2.40GHz)</td>
<td>2048 GB (8 x 30 MB L3)</td>
<td>2 x 250GB 7.2K SATA 143 x 200GB SSD SAS 16 x 600 GB 10K SAS</td>
<td>0.10 Seconds</td>
<td>4593.17</td>
</tr>
</tbody>
</table>

Tier A, Two Clients: IBM System x3650 M3

<table>
<thead>
<tr>
<th>CPU's Speed</th>
<th>Memory</th>
<th>Disks</th>
<th>tpsE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x Intel Xeon X5650 (2.66 GHz)</td>
<td>8 GB (2 x 1.5 MB L2) (2 x 12 MB L3)</td>
<td>2 x 250 GB 7.2K SATA</td>
<td>n/a</td>
</tr>
</tbody>
</table>

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 EGen components were verified to be v1.12.0.
- The transactions were correctly implemented.
- The database was properly scaled and populated for 2,300,000 customers.
- 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.
• The reported response times were correctly measured.
• All 90% response times were under the specified maximums.
• The measurement interval was representative of steady state conditions.
• The reported measurement interval was 120 minutes.
• The implementation used Redundancy Level 1.
• The Business Recovery Time of 02:02:23 was correctly measured.
• The 60 day storage requirement was correctly computed.
• The system pricing was verified for major components and maintenance.

Additional Audit Notes:

None.

Respectfully Yours,

Doug Johnson, Auditor

François Raab, President
Appendix A – Price Quotes
IBM
Ray Engler
3039 Cornwallis Road
Raleigh, NC 27709

Here is the information you requested regarding pricing for several Microsoft products to be used in conjunction with your TPC-E benchmark testing.

All pricing shown is in US Dollars ($).

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Unit Price</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>810-08527</td>
<td>SQL Server 2008 R2 Enterprise Edition Per Processor License Open Program - Level C Unit Price reflects a 20% discount from the retail unit price of $23,848.</td>
<td>$19,188</td>
<td>8</td>
<td>$153,504</td>
</tr>
<tr>
<td>P72-04217</td>
<td>Windows Server 2008 R2 Enterprise Edition Server License with 25 CALs Open Program - Level C Unit Price reflects a 43% discount from the retail unit price of $3,999.</td>
<td>$2,280</td>
<td>1</td>
<td>$2,280</td>
</tr>
<tr>
<td>P73-04980</td>
<td>Windows Server 2008 R2 Standard Edition Server License with 10 CALs Open Program - Level C Unit Price reflects a 31% discount from the retail unit price of $1,029.</td>
<td>$711</td>
<td>2</td>
<td>$1,422</td>
</tr>
<tr>
<td>N/A</td>
<td>Microsoft Problem Resolution Services Professional Support (1 Incident).</td>
<td>$259</td>
<td>1</td>
<td>$259</td>
</tr>
</tbody>
</table>


Defect support is included in the purchase price. Additional support is available from Microsoft PSS on an incident by incident basis at $259 call.

This quote is valid for the next 90 days.

Reference ID: TPCE_qhtplylGYLKTVUKfhpNjhiIIikQlf85757.DOC.
August 11, 2011

Dear Joe,

Noted below is the information you requested regarding pricing for the SMART Modular 2.5” SAS Solid State Drive (SSD) to be used in conjunction with your TPC benchmark testing.

All prices shown are in US Dollars ($). Pricing does not include applicable taxes or shipping charges, which may vary.

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Unit Price</th>
<th>Quantity</th>
<th>Extended Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG9XCA2E200GE01</td>
<td>200GB, 2.5” XceedIOPS SAS Solid-State Drive, eMLC</td>
<td>$1,800.00</td>
<td>158</td>
<td>$284,400.00</td>
</tr>
</tbody>
</table>

1 Unit price includes special product replacement support (7 day replacement TAT). Certain restrictions apply.
2 The minimum order quantity on this part number is 10 units.

The SMART SG9XCA2E200GE01 is currently available. For price confirmation and order assistance, please contact Ray Eustace at ClearComm Technical Sales at (919) 859-4400, or via email at smart@clearcommsales.com.

Notes:
1. This pricing is valid for thirty (30) days from the date of quotation.
2. All units are covered by a 5 year warranty from the date of shipment from SMART, subject to usage conditions defined in the product data sheet.

Sincerely,

Raymond Eustace
ClearComm Technical Sales (representative of SMART Modular Technologies, Inc.)
919-859-4400
reustace@clearcommsales.com

Ref quote ID: SMART ClearComm 20110811JH SG9XCA2E200GE01
cc: B. Heinze / SMART Modular
# Shopping Cart

<table>
<thead>
<tr>
<th>Qty</th>
<th>Product Description</th>
<th>Savings</th>
<th>Total Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hanns-G HW-173ABB Black 17&quot; 5ms Widescreen LCD Monitor</td>
<td>-$40.00 Instant</td>
<td>$119.99 $79.99</td>
</tr>
<tr>
<td>1</td>
<td>Rosewill RCW-717 3ft. /Network Cable Cat 6 (Crossover) Yellow</td>
<td></td>
<td>$2.99</td>
</tr>
</tbody>
</table>

Subtotal: $82.98

---

Don't want to wait for shipping! Try our new Will Call service.[learn more](#)

Some products can be picked up at our warehouse in City Of Industry, CA.[see address and hours](#)

Use Will-Call

---

Calculate Shipping

Zip Code: 27513  [UPS Guaranteed 3 Day -- $1.99](#)  

Shipping: $1.99

---

Redeem Newegg Gift Cards

Card Number:  Security Code:  

Apply Promo Code(s):

Promo Code: $0.00

New Newegg Preferred Account Customers: Get $15 off $100! Plus, No Interest if paid in full in up to 12 Months. Minimum purchase required.  
[Subject to credit approval. See Terms](#)

Grand Total: $84.97

---

[Policy & Agreement](#) [Privacy Policy](#) © 2000-2011 Newegg Inc. All rights reserved.