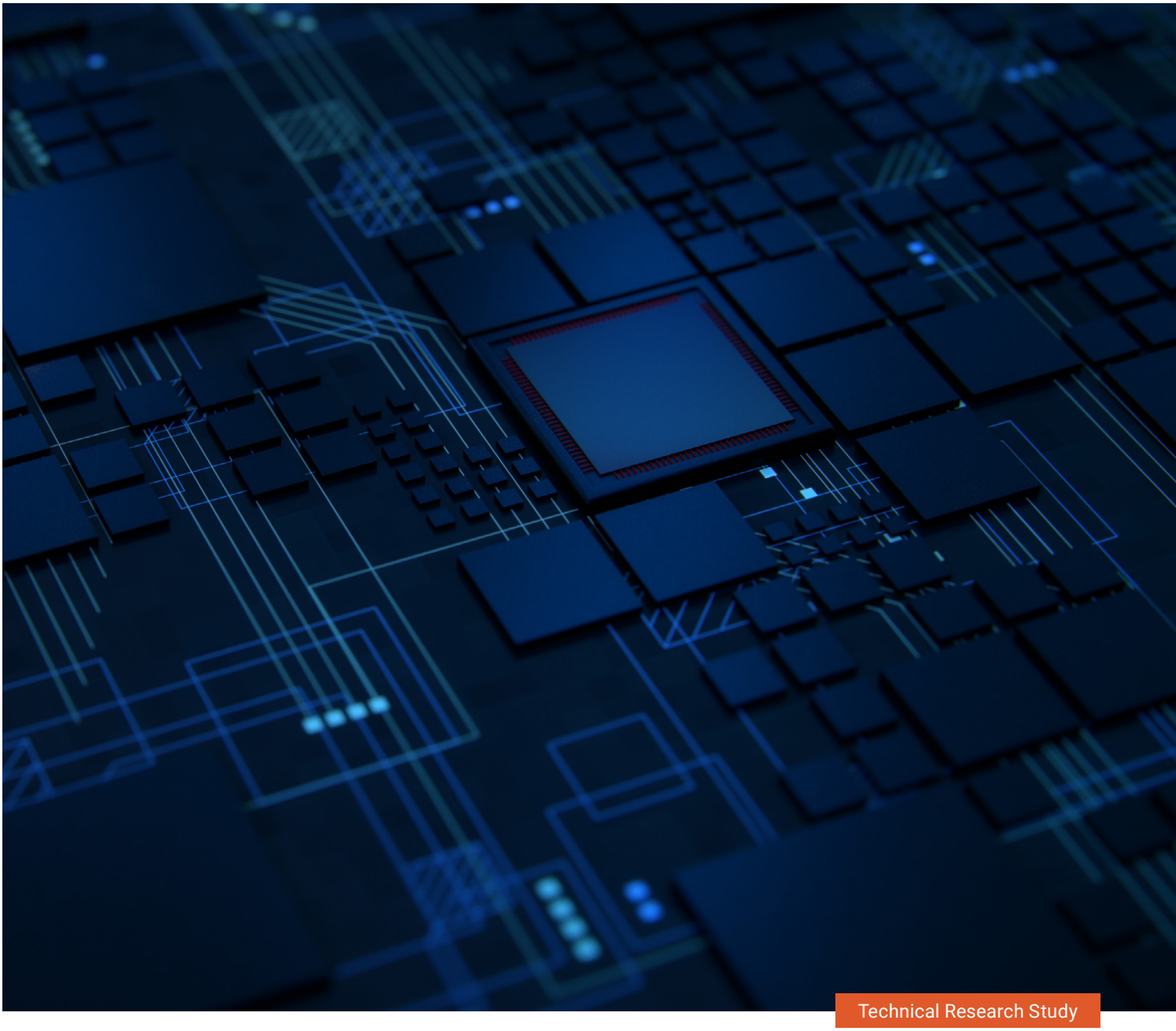

Technical Research Study

PROWESS

Oracle® Database TCO Compared: 3rd Generation Intel® Xeon® Processor–Based Systems Versus IBM® Power10™ Processor–Based Systems

Analysis conducted by Prowess Consulting finds that Oracle Database running on 3rd Generation Intel Xeon Scalable processor–based servers offers lower total cost of ownership (TCO) and better relative performance per TCO dollar compared to running on IBM Power10 processor–based servers.

Executive Summary

Businesses use Oracle® Database to run some of their most mission-critical, high-performance, and high-availability workloads. Popular systems for enterprise Oracle Database implementations fall into two camps: servers built around proprietary operating systems, such as IBM® Power® Systems running the IBM® AIX® operating system (OS), and systems built around pervasive operating systems, such as industry-standard systems powered by Intel® Xeon® processors running Linux®. Prowess Consulting put these competing system paradigms to the test to see which can provide the best total cost of ownership (TCO) running the industry's most popular enterprise relational database, Oracle Database.[1] For this study, Prowess compared four-socket IBM® processor–based systems (the only IBM server configuration currently available with IBM® Power10™ processors) and two-socket 3rd Generation Intel Xeon processor–based systems. We found a two-socket Intel® processor–based server powered by Intel Xeon Platinum 8358 processors, compared to a four-socket IBM Power E1080 server, provided:

- As much as **96 percent** lower TCO (see Appendix)
- Up to **18.5x** better relative performance per TCO dollar (see Table 3)
- Up to **1.2x** better performance per Oracle Database license (see Table 3)
- Up to **3.6x** better performance per watt (see Table 3)

This study underscores that capital expenditures (CapEx) are just the tip of the investment iceberg. Operating expenses (OpEx) for IBM Power Systems servers running the AIX OS are higher than for more widespread systems running Intel technology, requiring additional expenses including higher labor costs for specialized administrators for managing AIX OS.[2,3] Moreover, running the AIX OS can silo database systems and isolate them from the rest of organizations' data centers, and it creates a risk of vendor lock-in as the AIX OS is only supported on IBM Power Systems servers. Intel and Oracle offer validated, cloud-ready OS, compute, storage, and networking with full-stack hardware/software-converged systems that reduce complexity when deploying Oracle Database on Intel-based systems.

Socket Count for Servers Evaluated in This Study

At this report's time of writing, the IBM® Power10™ processor is only available in an up to 16 socket–capable system, such as the IBM® Power® System E1080 server. The configurations selected for the Intel® processor–based server and the IBM Power10 processor–based server were based on an expectation of achieving a similar level of online analytical processing (OLAP) database performance per system. Notwithstanding the greater number of processors in the IBM® server, the Intel processor–based server powered by Intel® Xeon® Platinum 8358 processors evaluated in this study is estimated to perform at near parity with the 4-socket IBM Power System E1080 server (see Table 3).

Market Landscape

Reliable and fast access to data is an ever more important part of every business. Relational database management systems (RDBMSs) continue to play a vital role in powering business operations in enterprises, and Oracle Database remains the most popular RDBMS.[1]

Oracle Database 19c

Oracle Database 19c continues the line of innovations and improvements that have marked the Oracle Database 12c family of databases. Building upon the multitenant, in-memory, and sharding capabilities of its predecessors, Oracle Database 19c provides critical enterprise database features.

Oracle Database 19c (which was released in early January 2019) is also the long-term release for the 12.2 product family of Oracle databases. This particular version will be supported through 2023. This status means that Oracle Database 19c will enjoy four years of premium support and a minimum of three years of extended support, with extended support available until 2026.[4,5] It is a database investment that will continue to power enterprises and businesses of many sizes for years to come.

Dueling Paradigms: IBM® Power® Processors vs. Intel® x86 Architecture

The latest IBM Power processor (the IBM Power10 processor) continues IBM's tradition of reliability inherited from its mainframes, with a focus on the performance of individual cores within the processor. However, getting all the enterprise functionality out of servers running on IBM Power processors requires specialized and increasingly rare administrative skills, such as using IBM's proprietary AIX OS. The AIX OS can provide other functionality, such as activating and deactivating processors and memory without restarting the server; but such capabilities can come at a steep price.

By optimizing its mainstream x86 processors for the data center and other demanding compute-intensive workloads, Intel has chosen an alternative approach of focusing on overall system performance. And rather than relying on a proprietary OS, servers powered by 3rd Generation Intel Xeon Scalable processors use pervasive industry-standard operating systems such as Linux and management tools used by most of the hardware organizations run. In addition, this is the processor-design strategy employed by Oracle itself, which uses Intel x86 processors in its high-end Oracle® Exadata® line of engineered database systems.

Prowess wanted to put these competing design philosophies to the test to see which strategy—compute specialization or overall performance—can deliver a better TCO for organizations seeking to modernize their business-critical database servers.

Overview of the Business-Case Comparison

This study compares both the CapEx to acquire the servers that run Oracle Database 19c and the necessary Oracle Database–related licenses, in addition to the OpEx associated with running those servers over a three-year period. The factors we considered in the OpEx analysis include:

- Software licensing and support
- Management
- Architectural differences

This study examines the business-case TCO considerations for a four-socket IBM Power E1080 server compared to a two-socket Intel processor–based server powered by 3rd Generation Intel Xeon Platinum 8358 processors.

Details of the Comparison Methodology: CapEx, OpEx, TCO, and Performance

Stand-out points of comparison include:

- CapEx
- OpEx
- Three-year TCO
- Performance

CapEx: Cost of Acquisition

Assessing the database systems, we found that a two-socket Intel processor–based server powered by Intel Xeon Platinum 8358 processors (32 cores per processor) with 1 TB of memory provides 96 percent savings on acquisition price compared to a four-socket IBM Power E1080 server with 40 cores total and 1 TB of memory (see Figure 1). (See the Appendix for a breakdown of the pricing.)

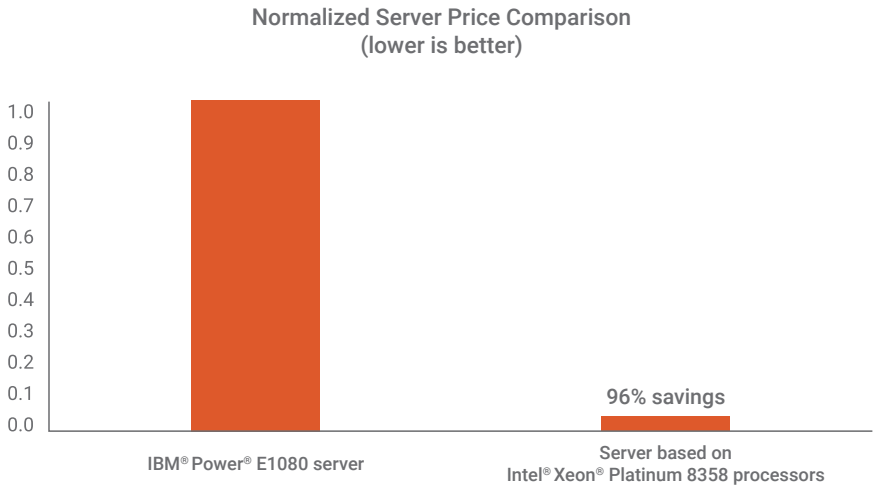

Figure 1. Normalized purchase-price comparison of a four-socket IBM® Power® E1080 server versus a two-socket Intel® processor–based server powered by Intel® Xeon® Platinum 8358 processors (lower is better)

OpEx: Ongoing Expenses

Software licensing, software maintenance costs, support costs, labor, and management costs are additional major expenses to consider when evaluating enterprise solution pricing.

Software Licensing and Support Costs

As with other aspects of the IBM Power processor stack, the AIX OS costs more than competing products. For example, Table 1 compares the cost of the AIX 7 Enterprise Edition OS for an IBM Power E1080 server with 40 cores over three years versus a comparable system running Oracle® Linux v8.5 with Premier Support and all enterprise features, along with enterprise virtualization software, which is 97 percent less expensive than the AIX offering.

Table 1. Three-year licensing costs of IBM® AIX® 7.2 Enterprise Edition for 40 cores versus Oracle® Linux® software for 64-cores (note: certain three-year costs have been divided by three for the purposes of this table's annual-costs comparison, but are representative of a single three-year license)

Software	Initial Cost	Annual Support Cost	Total Three-Year Cost[6,7]
IBM® AIX® on an IBM® Power® System			
IBM AIX 7.2 Enterprise Edition (40 cores)	$92,800.00	–	$283,110.16
IBM AIX software maintenance	–	$23,200.00	
IBM AIX 24x7 software support	–	$6,080.00	
IBM AIX 24x7 server support	–	$7,050.00	
IBM® Expert Care Advanced	–	$14,266.72	
IBM® PowerVM® Enterprise	–	Included	
IBM PowerVM Enterprise software maintenance	–	$12,000.00	
IBM PowerVM 24x7 software support	–	$840.00	
Oracle® Linux® v7/v8			
Oracle Linux	–	–	$6,897.00
Oracle Linux Premier Support per system	–	$2,299.00	
24x7 telephone and online support Oracle® Enterprise Manager for Linux management Oracle® Container runtime for Docker® Oracle Linux Virtualization Manager Zero-downstime patching with Oracle® Ksplice®	–	Included	

Power and Cooling

IBM Power E1080 servers are also power-hungry compared to servers powered by 3rd Generation Intel Xeon Scalable processors. In this particular study, the two-socket Intel processor–based server based on Intel Xeon Platinum 8358 processors cost an estimated 72 percent less to power and cool over three years than a four-socket IBM Power E1080 server (see Table 2). (Even accounting for the difference in the number of sockets, the Intel processor–based server still represents a 45 percent savings on a per-socket basis over the IBM Power E1080 server.) Table 2 provides details about the power and cooling costs of both servers.

Table 2. Three-year licensing costs of a four-socket IBM® Power® E1080 server versus a two-socket Intel® processor–based server powered by Intel® Xeon® Platinum 8358 processors

System	Power and Cooling	Annual Cost	Total Three-Year Cost[8,9]
4-socket IBM® Power® E1080 server			
Peak power consumption	2,714.0 W	$2,800.19	$16,806.83
Estimated cooling	9,261 BTU/h	$2,802.09	
2-socket Intel® Xeon® Platinum 8358 server			
Peak power consumption	737.9 W	$761.33	$4,569.60
Estimated cooling	2,518 BTU/h	$761.87	

Labor and Management Costs

Beyond the additional complexity of managing the AIX OS itself, the specialized skills required to manage systems running the AIX OS can cost more as well.[2,3] And beyond the cost of specialized administrative skills, the premium for an AIX admin might be higher still, because the responsibility of administering other Intel processor–based servers running the Linux OS would be folded into the broader IT organization, rather than being the sole responsibility of a specialist administrator.

The AIX OS can also impose additional costs for organizations that use it, because a server running the AIX OS can only be used for the workloads dedicated to that hardware; such limitations can detract from organizational flexibility in moving or consolidating workloads or even migrating to cloud as business imperatives change. Architectural differences between the AIX OS and other operating systems (such as Linux) can also necessitate additional programming overhead for applications in order to port them between operating systems.

Three-Year TCO

Altogether, with CapEx and OpEx totaled over a three-year period, an Intel processor–based server powered by Intel Xeon Platinum 8358 processors (32 cores per processor, 64 cores total) with 1 TB of memory provides up to 96 percent lower TCO than an IBM Power E1080 server with 10 cores per processor, 40 cores total, and 512 GB of memory (see Figure 2). (See the Appendix for a breakdown of the pricing.)

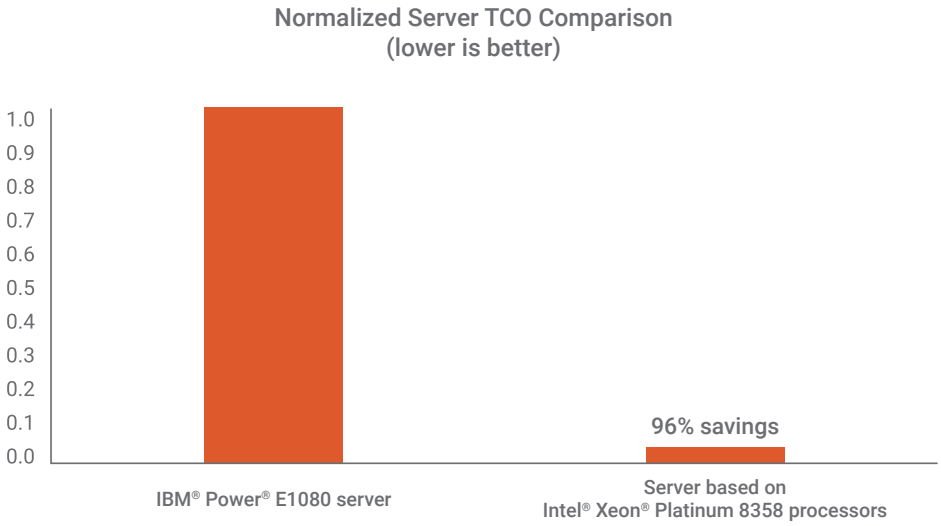

Figure 1. Normalized purchase-price comparison of a four-socket IBM® Power® E1080 server versus a two-socket Intel® processor–based server powered by Intel® Xeon® Platinum 8358 processors (lower is better)

Performance

Table 3 details the effective online transaction processing (OLTP) database performance of an IBM Power10 processor versus an Intel Xeon Platinum 8358 processor running the widely used, open-source database load testing and benchmarking tool, HammerDB benchmark, relative to TCO, Oracle Database licensing costs, and power consumption. Compared to the four-socket IBM Power E1080 server, the system powered by the Intel Xeon Platinum 8358 processors evaluated in this study can provide more than **18x better relative performance per TCO dollar** (see Table 3). Systems powered by the Intel Xeon Platinum 8358 processors can provide up to **1.2x performance per Oracle Database license** and up to **3.6x performance per watt of energy consumed** (see Table 3), compared to the IBM Power E1080 4-socket server. Oracle not only licenses Oracle Database by active CPU core, but it also weights this number of active CPU cores by a processor-core licensing factor. Table 3 shows the relevant core licensing factors for IBM Power processors and Intel Xeon processors. Because Oracle Database licenses can present a significant operational investment for companies, increasing performance per license can represent a substantial return on that investment.

Table 3. Performance comparison between a four-socket IBM® Power® E1080 server versus a two-socket Intel® processor–based server powered by Intel® Xeon® Platinum 8358 processors

	IBM® Power® E1080 Server	Intel® Xeon® Platinum 8358 Processor–Based Server
Sockets per system	4	2
Cores per system	40	64
Relative OLTP database performance[10]	1.00	0.97
Relative OLTP database performance per TCO dollar (versus an IBM Power E1080 server)[11]	1.00	18.54
Oracle® Database licensing core factor	1.0	0.5
Number of Oracle Database licenses required (number of system cores times Oracle core factor)	40	32
Relative OLTP database performance per Oracle Database license (versus an IBM Power E1080 server)[12]	1.00	1.21
High-end system power consumption[13,14]	2,714.0 W	737.9 W
Relative performance per watt consumed (versus an IBM Power E1080 server)[15]	1.00	3.67

3rd Generation Intel Xeon Scalable Processors Overview and Competitive Differentiators

3rd Generation Intel Xeon Scalable processors bring their own advantages for running Oracle Database, notably those stemming from the collaboration between Intel and Oracle and the unique capabilities of Intel® Optane™ persistent memory (PMem).

Advantages of Running Oracle Database 19c on Intel Xeon Scalable Processors

Intel and Oracle have a history of joint investment spanning more than 20 years. This close collaboration helps ensure that Intel architecture capabilities and features are enabled in both Oracle Database and the broader software offerings from Oracle. In-memory columnstore indexes in Oracle Database 19c can especially benefit from the Intel® Advanced Vector Extensions 512 (Intel® AVX-512) instruction set in 3rd Generation Intel Xeon Scalable processors. For example, Intel AVX-512 provides a 20 percent performance boost over the previous-generation Intel AVX2 instruction set.[16] And Intel AVX-512, coupled with Intel® AES New Instruction (Intel® AES-NI), accelerates data encryption and decryption to increase data protection compared to software security measures alone.

Beyond instruction sets and silicon-based encryption acceleration, 3rd Generation Intel Xeon Scalable processors boost Oracle Database performance in other ways. The mesh architecture in 3rd Generation Intel Xeon Scalable processors improves performance between all CPU cores (and threads) and memory.[17] And importantly for in-memory database workloads, the large memory capacity of 3rd Generation Intel Xeon Scalable processors (up to 6 TB per socket) can accommodate extremely large databases; keeping the database in memory avoids the need to read and write to storage, which can increase application latency (particularly during taxing OLTP activities).[18]

In addition to size, 3rd Generation Intel Xeon Scalable processors support core enterprise features of Oracle Database 19c:

- 3rd Generation Intel Xeon Scalable processor optimizations support multitenancy in Oracle Database 19c in order to deliver isolation, agility, and economies of scale.[19]
- Intel® Run Sure Technology complements reliability, availability, and serviceability (RAS) features in Oracle Database 19c, such as sparing and mirroring.[20]
- Intel® Ultra Path Interconnect (Intel® UPI) speeds up data transfers by connecting distributed shared memory, internal cores, input/output (I/O) hubs, and other Intel processors for additional performance in Oracle Database 19c.[21]

In addition to optimizations and enterprise features on the compute side, 3rd Generation Intel Xeon Scalable processors provide additional memory options that are not available with other processors, such as the opportunities for improving TCO provided by Intel Optane PMem.[22]

Conclusion

Compared to IBM Power E1080 servers, the lower system cost and compelling system-level performance of Intel processor–based servers powered by 3rd Generation Intel Xeon Scalable processors—both initially and over time—mean organizations can get more out of their hardware investments by using mainstream industry-standard hardware. For a two-socket Intel processor–based server powered by Intel Xeon Platinum 8358 processors compared to a four-socket IBM Power E1080 server, we found:

- As much as **96 percent** lower TCO (see Appendix)
- Up to **18.5x** better relative performance per TCO dollar (see Table 3)
- Up to **1.2x** better performance per Oracle Database license (see Table 3)
- Up to **3.6x** better performance per watt (see Table 3)

Compared to IBM's proprietary server offerings, which are more expensive and more challenging to administer, and which can create "data islands," the Intel system evaluated by Prowess provides organizations with solutions built on pervasive hardware and software that help prevent hardware lock-in and establish a more homogeneous, easier-to-manage data center that can pivot to meet future opportunities. Intel and Oracle can also offer validated, cloud-ready OS, compute, storage, and networking converged database-engineered solutions that further reduce complexity when deploying Oracle Database running on Intel-based systems.

Appendix

Three-year TCO comparison of 1 TB systems. TCO does not include costs associated with Oracle Database software licensing and support.

Component	IBM® Power® E1080 Server 4 x 10-Core IBM® Power10™ Processors	Intel® Processor–Based Server 2 x 32-Core Intel® Xeon® Platinum 8358 Processors
Processors	$185,625.00	$8,454.00
Processor activation	$200,000.00	–
Memory	$98,224.00	$6,704.00
Memory activation	$41,984.00	–
Chassis and other hardware costs	$86,783.00	$7,398.60
Hardware total	**$612,616.00**	**$22,556.60**
Purchase-price difference (hardware)		***$590,059.40***
IBM® AIX® 7.2 Enterprise Edition (40 cores, 3 years)	$92,800.00	–
IBM AIX software maintenance (3 years)	$69,600.00	–
IBM 24x7 software support (3 years)	$18,240.00	–
IBM 24x7 server support (3 years)	$21,150.00	–
IBM® Expert Care Advanced (3 years)	$42,800.17	–
IBM® PowerVM® Enterprise software maintenance (3 years)	$36,000.00	–
IBM PowerVM 24x7 software support (3 years)	$2,520.00	–
Oracle® Linux® Premier Support (3 years)	–	$6,897.00
Software total	**$283,110.17**	**$6,897.00**
Purchase-price difference (software)		***$276,213.17***
Maximum system power consumption[13,14]	2,714.0 W	737.9 W
Power-consumption total (3 years [8,766 hours] at $0.1178/kWh[23])	$8,400.58	$2,284.00
Maximum system power heat ouput[13,14]	9,261 BTU/h	2,518 BTU/h
Cooling total (3 years [8,766 hours] at $0.1178/kWh[23])	$8,406.26	$2,285.60
Power and cooling total	**$16,806.84**	**$4,569.60**
Power-consumption difference		***$12,237.24***
Grand total	**$912,533.01**	**$34,023.20**
Grand-total difference		***$878,509.81***
Relative difference	**26.8x TCO**	**96% lower TCO**

[1] DB-Engines. "DB-Engines Ranking." May 2022. https://db-engines.com/en/ranking.

[2] Average base pay: $122,194 per year as of May 4, 2022. Source: Glassdoor. "AIX Systems Administrator Salaries." www.glassdoor.com/Career/aix-systems-administrator-career_KO0,25.htm.

[3] Average base pay: $72,383 per year as of May 4, 2022. Source: Glassdoor. "Information Technology Administrator Salaries." www.glassdoor.com/Salaries/information-technology-administrator-salary-SRCH_KO0,36.htm.

[4] Oracle. "Oracle Database 19c: Introduction and Overview." February 2019. www.oracle.com/a/tech/docs/database19c-wp.pdf.

[5] Oracle. "Release Schedule of Current Database Releases (Doc ID 742060.1)." August 2020. https://support.oracle.com/knowledge/Oracle%20Cloud/742060_1.html.

[6] Total IBM software cost = $92,800.00 initial cost for IBM® AIX® 7.2 Enterprise Edition (40 cores) + ($23,200.00 annual cost for IBM AIX software maintenance + $6,080.00 annual cost for IBM AIX 24/7 software support + $7,050.00 annual cost for IBM server support + $14,266.72 annual cost for IBM® Expert Care Advanced + $12,000.00 annual cost for IBM® PowerVM® Enterprise software maintenance + $840.00 annual cost for IBM PowerVM 24x7software support) * 3 years = $283,110.16.

[7] Total software cost for an Intel® processor–based server running Oracle® Linux® = $2,299.00 annual cost for Oracle Linux Premier Support) * 3 years = $6,897.00.

[8] Total IBM power and cooling cost = (2,714.0 W 100 percent CPU utilization power draw for a four-socket IBM® Power® E1080 server (40 cores) + 9,261 BTU/h estimated heat output for a four-socket IBM Power E1080 server (40 cores)/3.41 BTU/h/W) * 0.001 kW/W * $0.1177/kWh average national commercial power cost for the United States (see endnote 23) * 8,766 hrs./year * 3 years = $16,806.83.

[9] Total Intel power and cooling cost = (737.9 W maximum power draw for a two-socket Intel® processor–based server powered by Intel® Xeon® Platinum 8358 processors + 2,518 BTU/h maximum estimated heat output for a two-socket Intel® processor–based server powered by Intel Xeon Platinum 8358 processors/3.41 BTU/h/W) * 0.001 kW/W * $0.1177/kWh average national commercial power cost for the United States (see endnote 23) * 8,766 hrs./year * 3 years = $4,569.60.

[10] Prowess estimate of relative OLTP database performance while running Oracle® Database comparing a baseline IBM® Power® E1080 server running 4 x 10-core IBM® Power10™ processors, 32 x 32 GB DDR4 memory with a value of 1.0 versus an Intel® processor–based server running 2 x 32-core Intel® Xeon® Platinum 8358 processors with 16 x 64 GB DRAM with a value of 0.97 based on public published HammerDB OLTP results.

[11] Prowess estimate for relative performance per TCO dollar, calculated by dividing relative OLTP database performance (see endnote 10) by TCO dollar (see the Appendix) for both an IBM® Power® E1080 server running 4 x 10-core IBM® Power10™ processors, 32 x 32 GB DDR4 memory (relative OLTP database performance (1.0)/TCO ($912,533.01) = 0.00000110) and an Intel® processor–based server running 2 x 32-core Intel® Xeon® Platinum 8358 processors with 16 x 64 GB DRAM (relative OLTP database performance (0.97)/TCO ($34,023.20) = 0.00002032). IBM system normalized to 1.0. Intel system relative performance per TCO dollar = 18.54 (0.00002032/0.00000110).

[12] Prowess estimate for relative OLTP database performance per Oracle® Database license calculated by dividing relative OLTP database performance (see endnote 10) by the number of Oracle Database licenses (from the Appendix) for both an IBM® Power® E1080 server running 4 x 10-core IBM® Power10™ processors, 32 x 32 GB DDR4 memory (relative OLTP database performance (1.0)/number of Oracle Database licenses (40) = 0.0250) and an Intel® processor–based server running 2 x 32-core Intel® Xeon® Platinum 8358 processors with 16 x 64 GB DRAM (relative OLTP database performance (0.97)/number of Oracle Database licenses (32) = 0.0303). IBM system normalized to 1.0. Intel system relative OLTP database performance per Oracle Database license = 1.21 (0.0303/0.0250).

[13] IBM. "IBM Systems Energy Estimator." Accessed June 2022. www.ibm.com/it-infrastructure/resources/energy-estimator/.

[14] Intel power-consumption estimate obtained by Prowess Consulting on May 4, 2022, for an Intel® processor–based server running 2 x 32-core Intel® Xeon® Platinum 8358 processors with 16 x 64 GB DRAM from www.thinkmate.com/.

[15] Prowess estimate for relative performance per watt calculated by dividing relative OLTP database performance (see endnote 10) by system power (from the Appendix) for both an IBM® Power® E1080 server running 4 x 10-core IBM® Power10™ processors, 32 x 32 GB DDR4 memory (relative OLTP database performance (1.0)/system power (2,714.0 watts) = 0.00037) and an Intel® processor–based server running 2 x 32-core Intel® Xeon® Platinum 8358 processors with 16 x 64 GB DRAM (relative OLTP database performance (1.0)/system power (737.9 watts) = 0.00136). IBM system normalized to 1.0. Intel system relative OLTP database performance per Oracle Database license = 3.6 (0.00136/0.00037).

[16] Source: Intel. "Oracle Database and Analytics on Intel® Architecture." September 2018. https://builders.intel.com/docs/datacenterbuilders/oracle-database-and-analytics-on-intel-architecture-brief.pdf. **Baseline configuration:** Oracle® Database 12c Release 2 in-memory with Intel® Advanced Vector Extensions 2 (Intel® AVX2), one node, 2 x Intel® Xeon® Platinum 8168 processor at 2.70 GHz (28 core parts used for test), 12 x 16 GB DDR4, 2,400 MHz DIMM, 1DPC (192 GB total memory) on Linux® 4.11.0 x86_64. Benchmark: Star Schema Benchmark. **Test configuration:** Oracle Database 12c Release 2 in-memory with Intel AVX-512 enabled, one node, 2 x Intel Xeon Platinum 8168 processor at 2.70 GHz (28 core parts used for experiment), 12 x 16 GB DDR4, 2,400 MHz DIMM, 1DPC (192 GB total memory) on Linux 4.11.0 x86_64. Benchmark: Star Schema Benchmark.

[17] Intel. "3rd Gen Intel® Xeon® Scalable Processors." June 2017. www.intel.com/content/dam/www/public/us/en/documents/product-briefs/xeon-scalable-platform-brief.pdf.

[18] Intel. "In-Memory Database: What It Is, How It Works, and Best Use Cases." www.intel.com/content/www/us/en/analytics/in-memory-database.html.

[19] Oracle. "Multitenant MAA Solutions." www.oracle.com/a/tech/docs/multitenant-maa.pdf.

[20] Intel. "Oracle Database and Analytics on Intel® Architecture." https://builders.intel.com/docs/datacenterbuilders/oracle-database-and-analytics-on-intel-architecture-brief.pdf.

[21] Intel. "Intel® Xeon® Processor Scalable Family Technical Overview." June 2019. www.intel.com/content/www/us/en/developer/articles/technical/xeon-processor-scalable-family-technical-overview.html.

[22] Intel. "3rd Gen Intel® Xeon® Scalable Processors." www.intel.com/content/www/us/en/products/docs/processors/xeon/3rd-gen-xeon-scalable-processors-brief.html.

[23] United States Energy Information Administration. "Electric Power Monthly." March 2022. www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.