About This Report

The present report provides an overview of the state of the high-performance transaction software market and its role and importance in both technical and business contexts, as well as an overview of SAP Adaptive Server Enterprise (ASE). The report explores the technological aspects of SAP ASE and how the solution enables scalability and increases efficiency, reliability, and speed for extreme transactional systems. The report reviews SAP ASE’s key benefits, and its role within SAP’s vision for the next generation of enterprise software applications.

The report contains the following main elements:

- Analyst perspective of the technical and business impacts of in-memory computing on high-performance transaction processing in the context of more demanding business needs and new enterprise software and computing architectures
- General industry perspective of the most common approaches to high-performance transaction processing and how SAP is working towards next-generation transactional systems
- A dive into the functions and features of SAP’s latest release of ASE. This section addresses:
  - The current SAP ASE solution from functional and architectural perspectives
  - SAP ASE’s new key capabilities for high-performance transactions
- Analyst observations
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High-speed Transactional Systems: The New Normal

Digital Transformation as a Driver for Technical Evolution

In the twenty-first century, we tend to think that the forces of digital transformation and of the digital economy are the ones defining—or redefining—the way we do business. This may be particularly true in transactional environments.

But organizations are realizing that the digital transformation process is, in fact, a virtuous cycle.

According to a Forbes Insights Report “Digital Economy, Doing Business In-the-Moment: Transforming Transaction Processing for the Digital Economy,” by 2020, transactions will be generated by billions of Internet-connected people and devices, including:

- 6.1 billion smartphone users
- 20.8 billion Internet of Things (IoT) devices
- 237.1 million wearable devices
- 400 million in-store beacons

In an increasingly mobile and connected world, companies of all sizes and in all industries aspire to streamline operations, ensure effective consumer experiences, and deliver data-driven products and services using high-speed transaction processing systems or extreme online transaction processing (XOLTP) systems.

To process these large-volume transactions, new and existing software and hardware systems need to perform at increased scale and speed.

The New Transactional Data System: Reshaping the Future of High-volume Operations with In-memory Technology

Transactions are also increasingly distributed and diverse. The demands are more complex, as most organizations are expected to deal with mixed data workloads, for example, to perform online transaction processing (OLTP) transactions, ad hoc queries, and operational reporting, as well as business intelligence and analytics processes, among other functions.

Transactional data systems therefore need to ensure accurate performance and deliver increases in transaction processing speed, volume, reliability, and efficiency as well as system availability.
Transactional systems are at the core of business. So, it makes sense for new in-memory–based transactional systems to preserve the capabilities essential for dealing with high-volume transactions, including support for:

- atomicity, consistency, isolation, durability (ACID)- and strict relational database management system (RDBMS)-compliant transactions
- relational compatible schemas and models
- multiple languages and application program interfaces (APIs), especially SQL, which remains the essential database access language
- a data storage model that enables effective physical and logical storage of data in row-oriented schemas

Added to these capabilities, transaction management systems are evolving to include software technology innovations to increase speed and efficiency, such as:

- Distributed and multi-core transaction capabilities via shared-disk clusters (SDCs), shared-nothing clusters (SNCs), and virtual (loosely) clustered systems to enable processing of transactions within multiple synchronized databases
- Support and/or incorporation of complex event processing capabilities, beyond the event processing of a database management system (DBMS), to enable the fast analysis of large volumes of data to identify key relations and patterns within data being ingested in real time (sensors, mobile, etc.) to initiate a response, such as flagging fraud before a transaction completes or rescheduling a shipment in a supply chain to avoid delays
- A shift from a centralized processing model to one that distributes processing capabilities to the edges of a network (as in edge computing and fog computing) to where transactions originate (devices)—changing the model from “bring data to the process” to “bring process to the data”
- Advanced in-memory computing or memory-optimized capabilities to maintain data within main memory, enabling high-performance processing of data in (near) real time

It is perhaps in-memory technologies that, along with scaling architectures, will be key to enabling the most significant change for new extreme transactional systems. At the same time, in-memory technology for XOLTP consistently shows clear technical benefits in terms of improved transaction processing performance.

Access and processing times are significantly reduced to enable higher performance with data in memory rather than on disk, while business logic processing can be simplified and executed faster, as some in-memory transactional databases can store procedures natively to reduce code overhead. The latches and locks common in disk-based tables can be eliminated, as transactional integrity can be ensured via methods such as optimistic multi-version concurrency, which creates new versions of a modified row to ensure ACID support within high concurrent workloads. Mixed OLTP and online analytical processing (OLAP) workloads can be executed in real time, providing enhanced
analytic capabilities for performing real-time tasks such as analytics or operational reporting.

The sum of these advantages is a cornerstone for increased adoption of in-memory technology for XOLTP. In-memory OLTP systems also facilitate the generation of memory-optimized tables, which can be significantly faster than disk-based tables.

Additionally, there are several inherent business value benefits to the use of in-memory technology. When typical transactional systems include analytics capabilities, OLTP information also enables decisions to be made in real time.

This can have an impact on both operational and management levels. By speeding up data capture and simplifying processes, the benefits at an operational level include the ability to optimize inventories, minimize business risks, lower operational costs, speed up time to market, and improve productivity. At the management level, this technology accelerates decision making so planning executives can exploit market opportunities faster, identify competitive threats sooner, and respond to market shifts more quickly.

The business potential of the application of in-memory technology within extreme OLTP scenarios is enormous, and would affect numerous industries spanning retail, manufacturing, communications, and financial services.

**In-memory Technologies in XOLTP Environments: Scalability and Performance**

In simple terms, an in-memory database system (IMDBS)—in contrast to a traditional database system, which is designed to store data on disk—is designed to store data entirely in main memory (Figure 1). Data that resides in main memory is much faster to process than when it is stored on disk, for several reasons. First, the design of an IMDBS tends to be simpler than disk-based systems, as process layers such as “caching” and file input/output (I/O) operations can be reduced in number, simplified, or even completely removed. Second, having data in memory makes it possible to eliminate multiple data transfers and redundant copies, which has the direct effect of minimizing demands on the central processing unit (CPU).
Based on this principle, vendors apply architectural variations to their solutions with the aim of increasing mainly two things: scalability and performance. Of course, processing speed, efficiency, reliability, and security and compliance, among other factors, are also improved.

From a transactional point of view, several technologies have emerged to improve in-memory processing. Many of them focus on different aspects, such as the efficient management of in-memory workloads on both single- and multi-core deployments to maintain/improve processing speed, efficient in-memory scaling capabilities in multi-core deployments to optimize shared memory usage and avoid conflict in critical memory sections, efficient processing of workloads for OLTP and operational reporting and analytics, and processing enabled for heavy-duty OLTP.

In this context, the use of in-memory technologies for XOLTP consistently shows clear technical benefits in terms of improved transaction processing performance. Some of these benefits mean that:

- Access and processing times are significantly reduced to enable higher performance with data in-memory rather than on disk.
- Business logic processing can be simplified and executed faster, as some in-memory transactional databases can store procedures natively to reduce code overhead.
- The latches and locks common in disk-based tables can be eliminated, as transactional integrity can be ensured via methods such as optimistic multi-version concurrency, which creates new versions of a modified row to ensure ACID support within high concurrent workloads.
- Mixed OLTP and OLAP workloads can be executed in real time, providing enhanced analytic capabilities for performing real-time tasks, such as analytics or operational reporting, within the same data structure.

Ensuring scalability and reliability of transactional systems is also a matter of great concern for organizations that have witnessed a huge explosion in the number of transactions to be processed or have developed extreme OLTP needs.
The explosion of transactions resulting from algorithmic trading, the digitalization of assets and related micro-transactions such as mp3 and e-book purchases that require no human intervention from order to delivery, the use of in-store beacons, and software bots is forcing companies to focus on two core requirements for extreme transactional databases: 1. transaction processing speed/scalability (more than 5,000 transactions per second) and 2. very high concurrency (more than 10,000 connections).

Computer hardware architectures have evolved to achieve reliable and efficient scalability.

1. **Read-only Scale-out**

Read-only scale-out, a “horizontal” scalability model, consists of a single writer node that replicates data to one or more reader nodes in the cluster, with the ability to add more nodes to a system. Thanks to the model’s ability to promote a reader node to writer, one immediate effect is to achieve high availability.

With streaming replication and solid-state drives (SSDs) to eliminate IO bottlenecks, replication latency decreases. As such, this scalability model has become more popular. However, providing full support requires the DBMS to have transaction routing capabilities or a logical cluster infrastructure service to routers and users between nodes, adding cost, complexity, and pressure for resources. These challenges would suggest a greater risk of hardware failure and limited usage and upgradability. Read-only scale-out remains a popular design option among open source providers.
2. Shared-disk Clusters

Another means of improving performance via horizontal scalability consists of building an SDC, in which multiple nodes connect to a single copy of the database storage. To ensure consistent operations, nodes are connected via high-speed/low-latency dedicated networks, which can coordinate concurrency control and synchronize cache content when necessary. As with the read-only scale-out model, when a node fails, the other nodes in the cluster can take control to achieve high availability.

Scaling SDCs can be challenging because it demands high networks speeds and large overheads, so it frequently ends up resembling shared-nothing clusters, with segmented applications and data partitioned across nodes. This type of situation will call for additional support for transaction routing services as well as transaction/federated query support to avoid cache synchronization overhead. Environmental restrictions can also limit the use of this scalability technique, as cloud deployments might not be able to dictate multiple low-latency interconnects and shared storage between nodes. Multiple writer nodes in SDC architectures must coordinate their locks around the cluster.

On the flip side, all data will be accessible from all cluster nodes, and any node will be able to read or write any portion of data as needed. This scalability is suitable for smaller systems, which can represent lower costs and support linear increases in capacity.

![Shared-disk cluster (SDC) model](image-url)
3. **Shared-nothing Clusters**

Originally developed to exploit massive parallel processing (MPP) disk I/O, SNCs, in which neither memory nor peripheral storage is shared between processors, apply partitioning or “database sharding” across nodes, with one “shard” per core “data.” The partitioning scheme is typically based around a single “shard key,” such as a bank account number.

This architecture requires the DBMS to implement a query processing engine that supports distributed query processing.

SNC architectures are not without some potential disadvantages: Transactions that span the shard key require a two-phase commit protocol or are disallowed, and large sets of data that do not contain the shard key could result in the query processing engine performing joins and other operations without the benefit of indices or duplicating common data across all the nodes, increasing disk space/memory requirements for each node. SNC architectures can also be write-limited, where writes span across multiple partitions, which also requires a two-phase commit.

To ensure high availability, such systems typically employ streaming replication for each node; consequently, the number of actual nodes in the cluster is approximately double the requirement.

SNCs generally do not experience distributed locking problems. With the correct node distribution, writes can be directed straight through to disk with lock mediation performed in memory. Only the processor has ownership of any single piece of data, so only one lock is required.

*Figure 4. Shared-nothing cluster model*
Additionally, SNCs are well suited for systems that need high-throughput writes. Because SNC approaches are largely software-based, they are also suitable for cloud deployments.

4. **Vertical Scalability**

Vertical scalability, or “scaling-up,” is perhaps the easiest and least costly solution. It focuses on improving performance within the capacity of the existing hardware by reducing the CPU cycles per unit of work, typically by adding resources to a single node in the system, normally CPUs or memory.

In the past, software demands regularly outpaced hardware development, so there was not much need to adopt vertical scalability. Today, with increased core densities and memory capacities, hardware has a life cycle of five to seven years and is being replaced with hardware that has four times the capacity. But as many companies aim to consolidate multiple hosts into a higher density single node, vertical scalability is gaining popularity, allowing them to do it relatively cheaply and easily.

However, this model requires database architectures that can scale on high-density cores and can support in-memory processing efficiently. So, for example, as some CPU hardware has instructions to raise a memory barrier when an operating system (OS) mutex is used, standard OS mutexes may have to be replaced to enable concurrency control in multithreaded programming.

On the positive side, this model allows more consistent performance by including cores and simplifying debugging. It also helps to ensure scaling control and efficiency.

![Figure 5. Vertical versus horizontal scalability](image-url)
5. MemScale Technology

MemScale (not to be confused with ASE Database MemScale described later in this report) is an emerging technology and alternative architecture for scalability. It combines the scalability potential of clustering with the absence of data partitioning of shared-memory architectures. MemScale involves software and hardware techniques that try to provide the best of both worlds for clusters and vertical scalability by allowing multiple nodes to be viewed as a single system image. As a result, software such as a DBMS does not need to implement complex engineering for shared-disk/nothing clusters that can scale using commodity hardware.

One of the benefits of MemScale is its ability to provide shared memory while avoiding coherency overhead, including power costs, due to its optimized management of shared resources. Its structure aims to preserve the best of shared-memory architectures while addressing the implicit scalability concern.

MemScale allows the execution of memory-intensive applications in the existing cores on a single node, but using as much memory as needed and not limited to the memory physically attached to that node.

There is no need to propagate invalidation messages to the other nodes because a given memory address will only be present in the caches contained in a single node. In this way, the lack of coherency among nodes in the cluster does not impose any limitation.

Additionally, MemScale provides acceptable performance results over slow memory technologies and large power-saving opportunities.

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*Figure 6.* Example of a global memory pool created from four nodes and accessed from one single node (Source: MEMSCALE: A Scalable Environment for Databases)
Taking Computing Power to the Next Stage

While there is no doubt in-memory technologies will keep evolving, they have become essential in mission-critical transactional environments. These technologies are now ready for adoption in many industries, and are being increasingly adopted in industries where processing speed and reliability are key for real-time intelligence gathering and efficient operational and tactical decision making, including banking and finance, insurance, gaming, analysis of sensor data, and more.

The symbiosis of software and hardware is encouraging the development of new technologies that improve the performance and reduce the complexity of computer systems, enabling information technology (IT) departments to break some of the traditional barriers that constrained their reaction time to business demands. In-memory technologies now have the potential to take computing power to the next level of processing, translating into significant business improvement.

Owing to the multiple technical and financial benefits of vertical, or scale-up, architectures, SAP is making significant investments in this area within SAP ASE. The SAP ASE RDBMS engine is intended to service extreme transaction processing data-centric applications that require high precision and ACID compliance.

These are some of the reasons why SAP is betting on the fact that shared-nothing and scale-up deployments are poised to overcome the challenges inherent to extreme OLTP deployments; the technology is evolving to be able to scale to comply with the most demanding requirements.

SAP ASE: Unleashing Transaction Process Power via State-of-the-art Technology

SAP Adaptive Server Enterprise (ASE), a database platform for extreme transaction processing, includes new capabilities to enhance performance, security, reliability, and resiliency.

The SAP ASE Database MemScale Option

SAP MemScale option extends scaling and concurrency capabilities and optimize processing speed via enhanced symmetric multiprocessing (SMP) server capabilities.

Specifically, SAP’s release of the database MemScale option addresses three major areas in extreme OLTP operations:

- Resource contention to enable more efficient access to shared computing resources, including cache management contention and OS memory concurrency controls due to the use of OS mutexes, as opposed to hardware atomic instructions.
• Reduce query latency and faster response time by reducing query processing overhead and data re-reading.
• Avoidance/reduction of read/write conflicts, specifically between readers and writers to data pages as well as between readers and writers to index pages.

Figure 7 gives a brief overview of SAP ASE’s new capabilities and features in the context of ASE’s novel in-memory computing capabilities, based on these key aspects.

Resource Contention
The lockless data cache (LLDC) is one of the non-MemScale scalability features implemented in ASE 16, often used to complement MemScale features. The LLDC feature is designed to reduce cache contention by eliminating the use of ASE spinlocks/OS mutexes when performing cache searches and cache modifications on named caches that used a relaxed cache strategy.

Using LLDC avoids this by using CPU lockless atomic instructions instead of spinlocks. As LLDC is not part of the MemScale option, it can be enabled with or without having to enable the MemScale option.

Although ASE had started using lockless CPU atomic instructions heavily by ASE 16 GA to replace spinlocks in key areas of code, ASE when deployed in Linux can use its new transactional memory feature, TSX, to take advantage of a hardware lock within x86 chipsets to improve query performance by reducing contention on locks and lashes. On Intel x86 chips with TSX-NI support, TSX can be enabled in ASE to allow lockless modifications to the lock hash tables. Generally, most Intel XEON processors after 2015 support TSX.

<table>
<thead>
<tr>
<th>MemScale Feature</th>
<th>Resource Contention</th>
<th>Query Speed / Latency</th>
<th>Read / Write Conflicts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cache Mgmt Contention</td>
<td>QB Memory Concurrency Controls</td>
<td>QP Overhead</td>
</tr>
<tr>
<td>Lockless Data Cache (LLDC)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simplified Native Access Plans (SNAP)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transactional Memory (TSX)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latch-Free B-Tree (LFB)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-memory Database (IMDB)</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Non-Volatile Cache (NVCache)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-Memory Row Store (IMRS)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hash Cached B-Tree (HCB)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Multi-Version Concurrency Control (MVCC)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Figure 7. Summary of SAP ASE’s new capabilities within its MemScale option (Courtesy of SAP)
Although the IBM Power8 and Oracle SPARC M7/T7 may support TSX, the only platform on which ASE currently supports TSX is Intel x86 with Linux (not Windows).

One of the newest SAP ASE features is the implementation of **data row caching (DRC) within an in-memory row store (IMRS)**. In DRC, newly inserted rows and frequently accessed rows are cached in a memory-optimized fashion, so finding the row is as simple as finding the row in the hash table—no redirection and no MRU-LRU re-linkage or other cache contention.

Similarly, finding a column is a simple process of jumping to the nth byte after the row overhead data. To speed updates as well as selects, considering that this is “hot” data, the data is stored in uncompressed from.

Another innovative aspect to the IMRS is that it has a separate transaction log called the sysimrslog. The key to scalability for this log is that it supports concurrent commits versus a single log semaphore.

While the data modifications are stored in user log cache/private log cache (ULC/PLC) pages and the normal ASE log allocates pages as necessary and enables flushes of due ULCs/PLCs of large transactions where transactions are often interleaved, with sysimrslog, data modifications are created as in-memory versions, even without being multiversion concurrency control (MVCC)-enabled.

At commit time, the server computes how much log space is necessary and reserves the full size (sysimrslog preallocates all space so there is no allocation step). Multiple transactions can thus be committed concurrently, as each is writing to its own reserved space.

**Query Speed/Latency**
To achieve more efficient query speed/latency, SAP ASE introduces a simplified native access plan (SNAP).

With SNAP, when a query is executed once, certain parts of the query will be compiled into native code so that subsequent executions will invoke the native code plans directly, having a shorter code path and executing fewer branch statements, which translates into improved performance. This feature includes:

- Statement cache plans, including those used for dynamic SQL (prepared statements)
- Plans with user stored procedures

Also, ASE includes an in-memory database (IMDB). Initially introduced as a separate option in 2007/2008 with the ASE 15.5 release, ASE’s IMDB is a non-durable database, meaning that if the system were to be shut down or to crash, the data would be lost as it was only ever in memory. However, since it is entirely in memory, ASE has a number of cache optimizations that would improve performance, such as elimination of the most recently used (MRU)-LRU chain,
wash marker, etc. In addition, one of the biggest bottlenecks in OLTP performance, the transaction log, has been bypassed, as committing transactions does not need to wait for the transaction log to be flushed to disk as part of the commit process. As a result, IMDB is a good solution for staging data or simulation data for logical units of work that would simply be restarted from the beginning (versus needing recovery to the failed point in the process).

The SAP ASE MemScale option also includes a non-volatile cache (NVCache), a query latency feature designed to facilitate queries in systems that have large volumes of data such that the active data portion exceeds the size of the available database memory. It does this by extending the ASE cache to an SSD device as a buffer cache extension.

NVCache essentially extends the buffer cache to an ultra-high-speed disk, such as an SSD. Additionally, SAP ASE’s MemScale option offers buffer cache extension using Flash integration. This feature speeds performance by allowing special named caches within SSDs and using SSD (flash) storage-based caching, which, as with regular named caches, can be created, dropped, and updated dynamically.

Another innovative ASE feature to improve resource contention is hash cached B-trees (HCBs). Aside from the familiar standard B-tree index and derivatives and hash-based indexes, the idea of an HCB is to cache the active portions of the B-tree index in a hash index structure and exploit lockless instructions to avoid contention. Given the disadvantages of hash indexing and considering how to determine active B-tree pages, the HCB implementation now supports unique indexes only, including unique and primary key constraints. Index rows are added to the HCB when the data row is added to the DRC; if a data row is aged out of the DRC, the index keys may remain in the HCB until space is needed; both the B-tree and HCB are maintained.

**Read/Write Conflicts**

To increase efficiency in dealing with read/write conflicts, two major features stand out: a latch-free B-tree (LFB) and a multi-version concurrency control feature.

Whereas an application with non-transactional latches would only latch an index page long enough to modify the rows or read them, the LFB feature provides a mechanism to eliminate the need for latches. The mechanism uses a delta-merge concept and in-memory structures that enable an application to perform index page modifications without impacting readers or other writers to the same index. This new feature aims to reduce even more contention by eliminating latches to improve read/write performance.

SAP ASE provides MVCC as an additional concurrency control, giving the choice to the database administrator whether a table uses standard American National Standards Institute (ANSI) locking/isolation levels or whether the table uses MVCC and non-ANSI snapshot isolation (Figure 8). Additional support for MVCC includes:
• Statement Snapshot—The query process only reads the most recent committed version of the data at the time the statement began execution. This is essentially equivalent to ANSI isolation levels 0 and 1.

• Transaction Snapshot—The query process only reads the most recent committed version of the data at the time of the first DML statement in the transaction. This is similar to chained mode in the sense that the first DML trips the condition. This is essentially equivalent to ANSI isolation levels 2 and 3.

• MVCC is supported for both IMRS and on-disk tables (OD-MVCC). Tables enabled for DRC can also have snapshot isolation enabled. Snapshot isolation on DRC tables creates the row versions in the IMRS store. Row version metadata is also tracked in the IMRS. As versions are no longer needed, separate garbage collection (GC) tasks clean up old versions and free the memory in the IMRS.

State-of-the-art Performance
Aside from these numerous improvements and new features, a couple of noteworthy aspects of the ASE MemScale option can be highlighted, one is the extensive work SAP has done to ensure improvement of performance and scalability will not mean significant extra effort for IT departments, ensuring small or even none is due to update. The other significant aspect has to do with enabling SAP new and existing customers to plan and foresee less disrupting scaling challenges within their existing SAP ASE deployments.
This option can, in my view, significantly improve the efficiency of SAP ASE in high core count machines and balance accelerated query execution and response time with faster storage performance.

To achieve state-of-the-art, competitive operational capabilities, enterprises will need to invest wisely in technologies that can match the pace of their growing business demands.

New mission-critical data processing initiatives must be able to actively respond to ever-increasing needs for speed and performance. As such, the evaluation of new technologies must take into account not just technology per se, but its fit within an organization’s increasing business demands.

SAP as a longtime front runner in the enterprise software market has in recent years made radical changes its technology paradigm in favor of incorporating new technologies, knowing that in due course significant numbers of organizations will be migrating to a state that ensures operational speed and efficiency for extreme processing.

Along with the shift to SAP HANA, an in-memory platform, with SAP ASE a high-speed transactional system, SAP is taking steps to ensure that organizations with growing and more demanding data-processing requirements will be able to keep the pace of business.

The bottom line is that in-memory technologies are here to stay. Organizations that leverage in-memory technologies will be completing their business quickly and effectively, in the least complex and most cost-efficient way possible.

SAP seems to be carefully crafting the future of its data management portfolio by incorporating in-memory capabilities across its entire enterprise software portfolio, beyond SAP HANA, its flagship in-memory platform. Interestingly, SAP is showing willingness to invest in and adopt technologies other than SAP HANA, as demonstrated by the availability of SAP ASE on the SAP HANA Platform as well as within Amazon Web Services.

SAP’s approach to incorporating in-memory capabilities into transactional systems appears to be feasible in a market that is rapidly being filled with new incumbents with innovative technologies. SAP needs to ensure continuous evolution in this arena if it aims to remain a data management powerhouse.
About the Author

Jorge García is a senior business intelligence (BI) and data management analyst for TEC. He has more than 20 years of experience in all phases of application development, database and data warehouse (DWH) design, as well as 9 years in project management, covering best practices and new technologies in the BI/DWH space.

Prior to joining TEC, García was a senior project manager and senior analyst developing BI, DWH, and data integration applications with Oracle, SAP Business Objects, and data integration. He has also worked on projects related to the implementation of BI solutions for the private sector, including the banking and services sectors. He has had the opportunity to work with some of the most important BI and DWH tools on the market.

García is a member of the Boulder BI Brain Trust.
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Technology Evaluation Centers Inc.
740 St. Maurice, 4th Floor
Montreal, QC H3C 1L5
Canada

Phone: +1 514-954-3665
Toll-free: 1-800-496-1303
Fax: +1 514-954-9739
E-mail: asktheexperts@technologyevaluation.com
Web site: www.technologyevaluation.com

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