

# Oracle Database 12c Release 2 for Data Warehousing and Big Data

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## Introduction

What is a data warehouse? Quite simply, a data warehouse is a database built for the purposes of analysis. “Data warehouses” encompass a huge range of applications today, from large-scale advanced analytical data stores supporting dozens of sophisticated analysts to pre-built business intelligence applications with tens of thousands of users, and from enterprise-wide data warehouses to departmental data marts. Data warehouses are now a mainstay of the IT infrastructure, enabling both long-term strategic planning and agile responses to new market conditions.

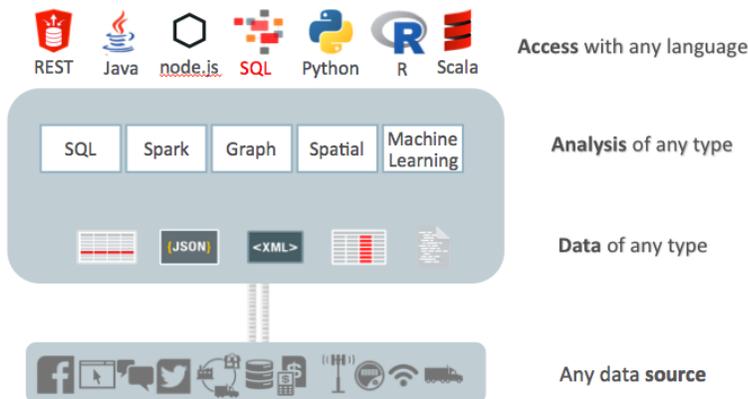
However, data warehousing is undergoing a major transition. The benefits of data warehouses are currently being realized in most organizations, partially if not wholly. The best practices for data warehouses are well established, and the technologies supporting data warehouses have become more and more mature. Today’s leading-edge organizations, seeking to further differentiate themselves through analytics, are expanding their data warehouses with “big data”.

This paper focuses on Oracle Database 12c Release 2’s capabilities for data warehousing and big data. The first section of this paper describes an overall architecture for big data illustrating the role of Oracle Database 12c Release 2 – available in the Oracle Cloud - in a ‘big data’ architecture. Subsequent sections highlight the capabilities in Oracle Database 12c Release 2 to support data warehouses and big data, focusing on hardware integration, performance, scalability and analytics.

## Big Data: The Evolution of Data Warehousing

Big data and data warehousing share the same basic goals: to deliver business value through the analysis of data. However, big data and data warehousing differ in the scope of their data. While the promise of enterprise data warehousing has always been to analyze all of organization's data, in practice data warehouses have traditionally sourced data predominantly from other databases; that is, an enterprise's data warehouse contains data from its enterprise financials systems, its customer marketing systems, its billing systems, its point-of-sales systems, and so on. Organizations have recently recognized that there is an increasing amount of data in today's rapidly digitizing world which is not captured in operational databases: clickstream logs, sensor data, location data from mobile devices, customer support emails and chat transcripts, and surveillance videos, just to name a few. Big data systems harness these new sources of data, and allow enterprises to analyze and extract business value from these immense data sets.

Big data is in many ways an evolution of data warehousing. To be sure, there are new technologies used for big data, such as Hadoop and NoSQL databases. And the business benefits of big data are potentially revolutionary. However, at its essence, big data requires an architecture that acquires data from multiple data sources, organizes and stores that data in a suitable format for analysis, enables users to efficiently analyze the data and ultimately helps to drive business decisions. These are the exact same principles that IT organizations have been following for data warehouses for years.



Oracle Big Data Platform: A New Information Architecture

The new information architecture that enterprises will pursue in the big data era is an extension of their previous data warehouse architectures. The data warehouse, built upon a relational database, will continue to be the primary analytic database for storing much of a company's core transactional data, such as financial records, customer data, and sales transactions. The data warehouse will be augmented by a big-data system, which functions as a 'data lake'. This will be the repository for the new sources of large volumes of data: machine-generated log files, social-media data, and videos and images -- as well as the repository for more granular transactional data or older transactional data which is not stored in the data warehouse. Even though the new information architecture consists of multiple physical data stores (relational, Hadoop, and NoSQL), the logical architecture is a single integrated data platform, spanning the relational data warehouse and the Hadoop-based data lake. Technologies such as Oracle



Big Data SQL make this distributed architecture a reality; Big Data SQL<sup>1</sup> provides data virtualization capabilities, so that SQL can be used to access any data, whether in relational databases or Hadoop or NoSQL. This virtualized SQL layer also enables many other languages and environments, built on top of SQL, to seamlessly access data across the entire big data platform.

## Oracle Database 12c Release 2 and Oracle Exadata: A Data Warehouse as a Foundation for Big Data

Even as new big data architectures emerge and mature, business users will continue to analyze data by directly leveraging and accessing data warehouses. The rest of this paper describes how Oracle Database 12c Release 2 provides a comprehensive platform for data warehousing that combines industry-leading scalability and performance, deeply-integrated analytics, and advanced workload management – all in a single platform running on an optimized hardware configuration.

### Exadata

The bedrock of a solid data warehouse solution is a scalable, high-performance hardware infrastructure. One of the long-standing challenges for data warehouses has been to deliver the IO bandwidth necessary for large-scale queries, especially as data volumes and user workloads have continued to increase. While the Oracle Exadata Database Machine is designed to provide the optimal database environment for every enterprise database, the Exadata architecture also provides a uniquely optimized storage solution for data warehousing that delivers order-of-magnitude performance gains for large-scale data warehouse queries and very efficient data storage via compression for large data volumes. A few of the key features of Exadata that are particularly valuable to data warehousing are:

- » **Exadata Smarts Scans.** With traditional storage, all database intelligence resides on the database servers. However, Exadata has database intelligence built into the storage servers. This allows database operations, and specifically SQL processing, to leverage the CPU's in both the storage servers and database servers to vastly improve performance. The key feature is "Smart Scans", the technology of offloading some of the data-intensive SQL processing into the Exadata Storage Server: specifically, row-filtering (the evaluation of where-clause predicates) and column-filtering (the evaluation of the select-list) are executed on Exadata storage server, and a much smaller set of filtered data is returned to the database servers. "Smart scans" can improve the query performance of large queries by an order of magnitude, and in conjunction with the vastly superior IO bandwidth of Exadata's architecture delivers industry-leading performance for large-scale queries.
- » **Exadata Storage Indexes.** Completely automatic and transparent, Exadata Storage Indexes maintain each column's minimum and maximum values of tables residing in the storage server. With this information, Exadata can easily filter out unnecessary data to accelerate query performance.
- » **Hybrid Columnar Compression.** Data can be compressed within the Exadata Storage Server into a highly efficient columnar format that provides up to a 10 times compression ratio, without any loss of query performance. And, for pure historical data, a new archival level of hybrid columnar compression can be used that provides up to 40 times compression ratios.

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<sup>1</sup> Though Big Data SQL is outside of the direct scope of this white-paper, it is a critical capability for integrating the data warehouse and the data lake. Interested readers should see "Oracle Big Data SQL Solutions Brief" for more information.

## Oracle Database In-Memory

While Exadata tackles one major requirement for high-performance data warehousing (high-bandwidth IO), Oracle Database In-Memory tackles another requirement: interactive, real-time queries. Reading data from memory can be orders of magnitude faster than reading from disk, but that is only part of the performance benefits of In-Memory: Oracle additionally increases in-memory query performance through innovative memory-optimized performance techniques such as vector processing and an optimized in-memory aggregation algorithm. Key features include:

- » **In-memory (IM) Column Store.** Data is stored in a compressed columnar format when using Oracle Database In-Memory. A columnar format is ideal for analytics, as it allows for faster data retrieval when only a few columns are selected from a table(s). Columnar data is very amenable to efficient compression; in-memory data is typically compressed 2-20x, which enables larger volumes of raw data to be stored in the in-memory column store.
- » **SIMD Vector Processing.** When scanning data stored in the IM column store, Database In-Memory uses SIMD vector processing (Single Instruction processing Multiple Data values). Instead of evaluating each entry in the column one at a time, SIMD vector processing allows a set of column values to be evaluated together in a single CPU instruction. In this way, SIMD vector processing enables the Oracle Database In-Memory to scan and filter billion of rows per second.
- » **In-Memory Aggregation.** Analytic queries require more than just simple filters and joins. They require complex aggregations and summaries. Oracle Database In-Memory provides an aggregation algorithm specifically optimized for the join-and-aggregate operations found in typical star queries. This algorithm allows dimension tables to be joined to the fact table, and the resulting data set aggregated, all in a single in-memory pass of the fact table.

Oracle Database In-Memory is useful for every data-warehousing environment. Oracle Database In-Memory is entirely transparent to applications and tools, so that it is simple to implement. Unlike a pure in-memory database, not all of the objects in an Oracle database need to be populated in the IM column store. The IM column store should be populated with the most performance-critical data, while less performance-critical data can reside on lower cost flash or disk. Thus, even the largest data warehouse can see considerable performance benefits from In-Memory.

## Query Performance

Oracle provides performance optimizations for every type of data warehouse environment. Data warehouse workloads are often complex, with different users running vastly different operations, with similarly different expectations and requirements for query performance. Exadata and In-Memory address many performance challenges, but many other fundamental performance capabilities are necessary for enterprise-wide data warehouse performance.

Oracle meets the demands of data warehouse performance by providing a broad set of optimization techniques for every type of query and workload:

- » **Advanced indexing and aggregation techniques** for sub-second response times for reporting and dashboard queries. Oracle's bitmap and b-tree indexes and materialized views provide the developer and DBA's with tools to make pre-defined reports and dashboards execute with fast performance and minimal resource requirements.
- » **Star query optimizations** for dimensional queries. Most business intelligence tools have been optimized for star-schema data models. The Oracle Database is highly optimized for these environments; Oracle Database In-Memory provides fast star-query performance leverage its in-memory aggregation capabilities. For other database environments, Oracle's "star transformation" leverages bitmap indexes on the fact table to efficiently join multiple dimension tables in a single processing step. Meanwhile, Oracle OLAP is a complete multidimensional



analytic engine embedded in the Oracle Database, storing data within multidimensional cubes inside the database accessible via SQL. The OLAP environment provides very fast access to aggregate data in a dimensional environment, in addition to sophisticated calculation capabilities (the latter is discussed in a subsequent section of this paper).

- » **Scalable parallelized processing.** Parallel execution is one of the fundamental database technologies that enable users to query any amount of data volumes. It is the ability to apply multiple CPU and IO resources to the execution of a single database operation. Oracle's parallel architecture allows any query to be parallelized, and Oracle dynamically chooses the optimal degree of parallelism for every query based on the characteristics of the query, the current workload on the system and the priority of requesting user.
- » **Partition pruning and partition-wise joins.** Partition pruning is perhaps one of the simplest query-optimization techniques, but also one of the most beneficial. Partition pruning enables a query to only access the necessary partitions, rather than accessing an entire table – frequently, partition-pruning alone can speed up a query by two orders of magnitude. Partition-wise joins provide similar performance benefits when joining tables that are partitioned by the same key. Together these partitioning optimizations are fundamental for accelerating performance for queries on very large database objects.

The query performance techniques described here operate in a concerted fashion, and provide multiplicative performance gains. For example, a single query may be improved by 10x performance via partition-pruning, by 5x via parallelism, by 20x via star query optimization, and by 10x via Exadata smart scans – a net improvement of 10,000x compared to a naïve SQL engine.

Orchestrating the query capabilities of the Oracle database are several foundational technologies. Every query running in a data warehouse benefit from:

- » A **query optimizer** that determines the best strategy for executing each query, from among all of the available execution techniques available to Oracle. Oracle's query optimizer provides advanced query-transformation capabilities, and, in Oracle Database 12c, the query optimizer adds Adaptive Query Optimization, which enables the optimizer to make run-time adjustments to execution plans.
- » A **sophisticated resource manager** for ensuring performance even in databases with complex, heterogeneous workloads. The Database Resource Manager allows end-users to be grouped into 'resource consumer groups', and for each group, the database administrator can set policies to govern the amount of CPU and IO resources that can be utilized, as well as specify policies for proactive query governing, and for query queuing. With the Database Resource Manager, Oracle provides the capabilities to ensure that data warehouse can address the requirements of multiple concurrent workloads, so that a single data warehouse platform can, for example, simultaneously service hundreds on online business analysts doing ad hoc analysis in a business intelligence tool, thousands of business users viewing a dashboard, and dozens of data scientists doing deep data exploration.
- » **Management Packs** to automate the ongoing performance tuning of a data warehouse. Based upon the ongoing performance and query workload, management packs provide recommendations for all aspects of performance, including indexes and partitioning.

## Data Management

Data warehouses, being the largest database in an IT organization, can present different data management challenges than typical OLTP database. Oracle provides unique advantages for running Oracle data warehouses online, with all data always available.

### Partitioning

Oracle Partitioning is essential for managing large databases. It enables a "divide and conquer" technique for managing the large tables in the database, especially as those tables grow.



Although your database may have twice as much data next year as it does today, your end-users are not going to tolerate their application running twice as slow, your database is not going to be given twice as much time to complete maintenance and batch processing, and your IT managers are not going to double the hardware budget for the data warehouse. Partitioning is the feature that allows a database to scale for very large datasets while maintaining consistent performance, without unduly increasing administrative or hardware resources. Partitioning divides large tables up into smaller pieces, and thus allows many types of typical maintenance operations and end-user queries to be maintained at constant performance level even as the data grows.

Oracle leads the industry with the most comprehensive set of partitioning technologies, with numerous methods for partitioning tables, along with the capability for DBA's to define custom partitioning schemes; a rich set of administrative commands for partitioned tables; and a partition adviser to guide administrators on how best to implement partitioning.

Partitioning also enables Oracle's Advanced Data Optimization capabilities. A single table, when partitioned, can be distributed across multiple storage tiers. Older, less-frequently accessed data, corresponding to older partitions, can be compressed and/or stored on less expensive storage tiers, while newer data is stored on faster storage tiers. Advanced Data Optimization automates the process of modify data's storage characteristics based on the usage of that data.

#### Compression

Compression capabilities are used within every large data warehouse. As customers look to store larger and larger volumes of data, compression is a natural solution. Oracle provides industry-leading compression technology, with a breadth of compression techniques that enables every table in a data warehouse to be compressed:

- » "OLTP" Compression: Part of Oracle Advanced Compression, this technique delivers a typical compression ratio of 3:1 for data warehouses, with virtually no negative impact on query performance. This compression technique enables efficient updates to support compression for even data warehouse tables which are 'trickle-fed' or otherwise updated frequently.
- » Query Compression: Based upon Exadata Hybrid Columnar Compression, this technique delivers a typical compression ratio of up to 10:1 for data warehouses, with virtually no negative impact on query performance.
- » Archive Compression: Based upon Exadata Hybrid Columnar Compression, this technique delivers a typical compression ratio of up to 40:1 for data warehouses, but does entail trade-offs in query performance.

#### Read Consistency and Online operations

Oracle provides unique, patented read-consistency model to ensure that data loads never impact query performance. Oracle solves the challenges of concurrent access through a technology called multi-version read consistency; this unique technology has been the foundation of Oracle's concurrency model for over 15 years. Multi-version read consistency guarantees that a user always sees a consistent view of the data requested. If another user changes the underlying data during the query execution (such a trickle-feed update of a large data warehouse table), Oracle maintains a version of the data as it existed at the time the query began. The data returned to the query always reflects the state of the database (including all committed transactions) at the point in time at which the query was submitted regardless of what other updates may be occurring while the query is running. With this technology, Oracle is uniquely positioned to handle near real-time data loads within data warehouse environments, since queries and updates can occur simultaneously without blocking each other.

Oracle also provides online operations. Even for occasional data-maintenance operations, taking a data warehouse table offline is not viable. Thus, Oracle allows maintenance operations, such as moving a partition or table to be performed online, without impacting ongoing query or DML operations.



Data warehouses have become mission critical, and an area that is frequently overlooked is that they must now function as mission critical systems, by being fully available during load/update operations and during data-maintenance operations.

## Analytics and SQL

Technologies such as spatial analysis, statistical analysis, predictive analytics, and OLAP are hardly new to data warehousing and business intelligence. However, each of these technologies typically has its own 'data engine'. An enterprise-wide analytics environment could maintain a dozen different engines, each requiring their own copies of the data, their own management infrastructure, their own security administration, and their own high-availability infrastructure. Even more daunting, each engine may have its own API's, its own query language, and its own set of developer tools and end-user tools.

Recent Big Data architectures provide one solution to this dilemma. Rather than replicating multiple copies of data into different analytic servers, organizations are creating data lakes in HDFS (Hadoop) in order to provide a single data source for multiple analytical engines. One copy of data stored in HDFS can be accessed by many different processing engines -- not only by Apache projects like Spark, but also by Oracle using Oracle Big Data SQL. The data lake is becoming a popular platform for analytic sandboxes. This architecture addresses a core challenge of multiple, siloed analytic environments by consolidating multiple engines on a single data set, while still allowing data scientists a choice of tools and languages.

Oracle Database provides an additional benefit. Not only does the Oracle Database provide multiple types of analytics (text, spatial, graph, statistics, predictive analytics) against relational data, but the Oracle Database also provides a single language, SQL, across all of these analytic techniques.

The integration of analytics within the Oracle Database provides a host of advantages unavailable to stand-alone environments. For example, does your standalone OLAP server scale across large clusters of servers? How easily does your statistics engine integrate into your user authentication server? And can it transparently implement all of your data security policies? How easily can you integrate the results of your spatial analysis with your data warehouse data? Within Oracle Database, all of these issues are solved simply due to the deep integration of analytic capabilities in the database.

### SQL Extensions for Analytics

The SQL language continues to evolve to enable more and more complex analysis. Moving averages, lag/lead, ranking, and ratio-to-report calculations are ubiquitously used in data warehouses today – and Oracle helped to pioneer these standardized SQL extensions.

Oracle continued to extend SQL in Oracle Database 12c Release 1 with its new Pattern Matching capabilities. SQL Pattern Matching introduces a new SQL syntax, along with optimized performance, for detecting patterns in a sequence of events stored in a database table. For example, one might want to look for trends in a stock price, or for suspicious behavior stored in activity log. With Oracle 12c, these queries can be expressed in a simple syntax, without requiring recursive joins or other complex SQL constructs.

### Approximate Query Processing

With Oracle Database 12c Oracle introduced the first approximate processing function in the database, namely approximate count distinct. In many cases the level of accuracy needed – i.e. good enough is in fact the perfect answer. With approximate count distinct, an approximate answer that is for example within 1% of the actual value can be returned extremely quickly. This enables new classes of data analysis with appropriate accuracy, without



excessive resource utilization and fast response time. Oracle Database 12c Release 2 has expanded the support for aggregation and data discovery based on approximate results by providing a richer library of approximate functions which now includes: `APPROX_COUNT_DISTINCT`, `APPROX_PERCENTILE`, and `APPROX_MEDIAN`. All of those functions are also embedded in the materialized view framework and can be leveraged for partial pre-aggregation and query rewrite.

#### SQL Extensions for Non-relational Data

Oracle's SQL is able to query many other data structures beyond just relational tables. Most recently, Oracle added extensions to SQL to query JSON documents. Attributes from JSON documents can be queried as relational columns using standard SQL queries.

#### Analytic Views

Analytic views are a new type of view in Oracle Database 12c Release 2 that embed joins, aggregation rules, hierarchical metadata, and complex measure calculations in a single view. Analytic views are queried with very simple SQL statements; the calculation and aggregation rules are handled within the view not in the SQL statement. Thus, analytic views enable much more rapid development of new BI applications and reports.

#### Advanced Analytics

Oracle Advanced Analytics offers a combination of powerful in-database predictive-analytics algorithms and open source R algorithms, accessible via SQL and R languages.

These analytic capabilities include a dozen data-mining algorithms implemented in the Oracle Database (including algorithms for classification, clustering, regression, anomaly detection, and associations); SQL functions for basic statistical techniques; and tight server-side integration with open-source R to enable R programmers to realize the full performance and scalability of the Oracle database platform and also provide access to the entire functionality of the R ecosystem on data stored in the Oracle database.

By providing a range of GUI and IDE options, Oracle Advanced Analytics allows business users, statisticians, and data scientists to tap directly into the large data volumes and extensive processing capacity of the Oracle Database, using an environment appropriate to each end-user. SQL-savvy data scientists can directly use SQL, statisticians with experience in R can continue to write R programs and utilize R-based GUIs, and business users can leverage Oracle's Data Miner extension in SQL Developer.

#### OLAP

Oracle OLAP is a full-feature online analytical processing (OLAP) engine embedded in the Oracle Database. Oracle OLAP enhances data warehouses by improving query performance (as discussed in the performance section) and by adding enriched analytical content.

The core feature of Oracle OLAP is cubes. Managed within the Oracle database, cubes store data within a highly optimized multidimensional format. Cubes provide scalable and compressed storage of dimensional data, fast incremental update, fast query performance, and the ability to compute or store advanced analytical calculations.

Oracle's strategy with Oracle OLAP is to bring these core OLAP advantages into the data warehouse. This is achieved by exposing the key capabilities of Oracle OLAP via standard SQL, so that any business intelligence tools or other SQL-based application can leverage OLAP.



## Conclusion

Oracle Database is the market leader for data warehousing, built upon a solid foundation of scalability and performance, and augmented by innovative features such as Oracle's unique read-consistency model for near-real-time data warehouses and a flexible and powerful set of in-database analytic capabilities. As data warehouses evolve into broader big data platforms, the key requirements for fast query performance, scalable data management, and flexible analytics not only remain, but also must extend to the entire big data platform. With Oracle Big Data SQL, Oracle delivers the power of its Database across the big data ecosystem, extending and co-existing with the Hadoop ecosystem.



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