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Upgrade Path Validation from Long-Term Support to Innovation Release Databases: Compatibility and Rollback Strategies for 19c to 23ai Transitions

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ABSTRACT: Enterprise database modernization has entered a critical inflection point as Oracle's Long-Term Support (LTS) release, version 19c, approaches its extended support horizon while Oracle Database 23ai introduces paradigm-shifting capabilities including native AI vector search, JSON Relational Duality, True Cache architecture, and extensive SQL domain enhancements. This article presents a comprehensive, empirically grounded framework for validating upgrade paths from Oracle 19c to Oracle 23ai in production environments. We systematically analyze compatibility boundaries across application tiers, middleware stacks, and operating-system dependencies; detail a five-phase upgrade validation lifecycle; quantify performance transformation profiles from benchmark studies; and construct a multi-layered rollback architecture capable of meeting sub-four-hour recovery objectives. Drawing on case evidence from financial services, healthcare informatics, and telecommunications deployments, we demonstrate that disciplined pre-upgrade assessment reduces post-migration incidents by up to 73%, and that Flashback Database combined with Data Guard role transitions can consistently meet RTO targets below two hours for databases under 10 TB. The article concludes with a decision framework enabling database architects to select among in-place upgrade, clone-and-upgrade, and parallel-run strategies based on availability windows, data-volume constraints, and organizational risk tolerance.

KEYWORDS: Oracle Database 23ai · Oracle 19c LTS · Database Upgrade Validation · Rollback Strategies · AI Vector Search · JSON Relational Duality · Database Migration · Flashback Technology · Data Guard · Enterprise Database Architecture

I. INTRODUCTION

The Oracle database landscape in 2024–2025 is defined by a fundamental dichotomy between stability and innovation. Oracle Database 19c, released in January 2019 as a Long-Term Support edition, has become the most widely deployed Oracle version in enterprise history, accumulating an installed base estimated at over 340,000 production instances globally by mid-2024 [1]. Its appeal derives from a guaranteed support runway extending to December 2026 for premier support and through 2027 under extended coverage - providing organizations the temporal comfort to plan large-scale migrations deliberately rather than reactively [2].

Contrastingly, Oracle Database 23ai - launched in 2024 as an Innovation Release - introduces capabilities that fundamentally expand the database's functional envelope. Native AI vector storage and similarity search, JSON Relational Duality views, the True Cache distributed in-memory tier, SQL Domains, and over 300 additional developer-facing enhancements position 23ai not merely as an incremental improvement but as a new architectural paradigm [3]. The designation "ai" in the product name itself reflects Oracle's thesis that the database must become an active participant in intelligent application pipelines, not merely a passive data store [4].

This creates both an opportunity and a challenge for database architects. The opportunity is transformational: organizations that successfully migrate to 23ai gain access to hybrid transactional/analytical processing at a new tier of integration, native semantic similarity capabilities competitive with dedicated vector databases, and dramatically simplified application architectures for JSON-centric workloads. The challenge is operational: every version boundary introduces compatibility risks, deprecated feature exposures, changed optimizer behavior, and the ever-present risk of regression in workloads that have been stable for years on 19c.

Key Insight: The 19c-to-23ai transition is not a conventional dot-release upgrade. It spans two major version families, crosses an Innovation/LTS boundary, and introduces features - particularly AI-native constructs and JSON Duality - that



represent genuine paradigm shifts in how application teams interact with the database engine. Treating it as routine carries substantial operational risk.

This article addresses that challenge systematically, organized around four primary research questions:
RQ1: What compatibility dimensions must be assessed before initiating an Oracle 19c-to-23ai upgrade?
RQ2: Which upgrade execution strategies are appropriate under differing operational constraints?
RQ3: How do performance and functional characteristics of representative workloads change after migration to 23ai?
RQ4: What rollback architectures reliably meet enterprise RTO/RPO requirements when a 23ai migration must be reversed?

300k+	300+	70%	<2h
19c Production Instances Globally (2024)	New Features in Oracle 23ai vs 19c	Incident Reduction with Pre-Upgrade Assessment	Achievable RTO with Flashback + Data Guard

II. THE ORACLE VERSION LANDSCAPE: LTS VS. INNOVATION RELEASES

2.1 Release Model Evolution
Oracle adopted a bifurcated release cadence starting with the 18c/19c era, drawing conceptual influence from the Linux kernel's stable/mainline model and OpenJDK's LTS framework. Under this model, Long-Term Support releases receive full premier support for five years plus extended support for an additional three, yielding a predictable eight-year lifecycle. Innovation Releases are released on an approximately annual basis and receive twelve to eighteen months of premier support, after which organizations are expected to upgrade to the next Innovation or LTS release [5].

Oracle 23ai is the first Innovation Release to carry the "ai" brand suffix, reflecting the depth of artificial-intelligence integration - specifically the native vector embedding storage, approximate nearest-neighbor (ANN) search operators, and AI-assisted SQL syntax extensions. This naming shift signals that Oracle views AI integration as a first-class architectural capability rather than an add-on extension layer [6].

TABLE 1. ORACLE DATABASE RELEASE TIMELINE AND SUPPORT HORIZON

Version	Release Type	GA Date	Premier Support End	Extended Support End	Key Innovation
18c (18.3)	Innovation	Feb 2018	Jun 2021	Jun 2023	Multitenant default, Autonomous features
19c (19.3)	LTS ★	Jan 2019	Apr 2024	Apr 2027	Stability, Active Data Guard, DML Redirect
21c (21.3)	Innovation	Aug 2021	Apr 2024	N/A	Blockchain Tables, Native JSON type
23c / 23ai	Innovation	2023 (free), 2024 (enterprise)	2025 (est.)	N/A	AI Vector Search, JSON Duality, True Cache
25c (next LTS)	LTS (projected)	2025–2026	TBD	TBD	Consolidation of 23ai features + stability

Table 1: Oracle Database release timeline. LTS = Long-Term Support. Dates per Oracle Lifetime Support Policy Q4 2024 [5].



2.2 Strategic Implications of the 19c-to-23ai Gap

Unlike a minor patch-level upgrade within a single major version, the 19c-to-23ai transition traverses a four-version gap (19c → 21c → 23ai in feature lineage) and crosses the LTS-to-Innovation boundary. Several strategic implications follow:

Feature Deprecation Accumulation: Deprecated features from 21c compound with 23ai deprecations, requiring multi-generation compatibility review.

Optimizer Behavioral Divergence: The Cost-Based Optimizer (CBO) in 23ai incorporates machine-learned statistics estimations unavailable in 19c, potentially transforming execution plans.

Middleware Recertification: Application servers, ORM frameworks, and JDBC/OCI drivers certified against 19c may require version updates to interoperate correctly with 23ai protocol changes.

III. ORACLE 23AI FEATURE ANALYSIS FOR MIGRATION PLANNING

3.1 AI Vector Search Architecture

The most architecturally significant addition in Oracle 23ai is the native VECTOR datatype and associated distance-function SQL operators. Organizations currently supplementing Oracle 19c with dedicated vector databases (pgvector-on-PostgreSQL, Pinecone, Weaviate, Milvus) for embedding-based similarity search can consolidate this workload back into Oracle 23ai, eliminating cross-database synchronization pipelines and simplifying consistency management [7].

The VECTOR type supports embeddings of arbitrary dimension with FP32, FP64, INT8, and BINARY precision. The VECTOR_DISTANCE() operator supports L2 (Euclidean), cosine, dot-product, and Hamming metrics. Index structures use Hierarchical Navigable Small World (HNSW) graphs - the same algorithm dominating standalone vector database benchmarks - with approximate nearest-neighbor guarantees [8].

-- Oracle 23ai: Native vector storage and similarity search

```
CREATE TABLE product_embeddings (
  product_id NUMBER PRIMARY KEY,
  description VARCHAR2(4000),
  embedding VECTOR(1536, FLOAT32) -- OpenAI ada-002 dimension
);
```

-- Create HNSW vector index

```
CREATE VECTOR INDEX idx_prod_embed
ON product_embeddings(embedding)
ORGANIZATION INMEMORY NEIGHBOR GRAPH HNSW
WITH TARGET ACCURACY 95
DISTANCE COSINE
PARAMETERS (type HNSW, neighbors 32, efconstruction 500);
```

-- Similarity search: find top-10 nearest neighbors

```
SELECT product_id, description,
  VECTOR_DISTANCE(embedding, :query_vector, COSINE) AS similarity
FROM product_embeddings
ORDER BY VECTOR_DISTANCE(embedding, :query_vector, COSINE)
FETCH FIRST 10 ROWS ONLY;
```

3.2 JSON Relational Duality Views

JSON Relational Duality is a novel construct that exposes relational tables simultaneously as JSON documents with full CRUD semantics. Applications written against document-model assumptions can read and write through duality views, with Oracle transparently maintaining referential integrity and relational normalization in underlying tables [9]. From a migration planning perspective, existing applications using Oracle's SODA API on 19c can be incrementally migrated to duality views without schema redesign; new application tiers developed on 23ai may use duality view ETAG-based optimistic locking, which requires developer education if teams are accustomed to row-level pessimistic locking.



3.3 True Cache

True Cache is Oracle's answer to read-side caching tiers (Memcached, Redis) for SQL query results. A True Cache instance maintains a synchronized, read-only subset of the primary database's buffer cache and log stream, serving SQL queries locally with sub-millisecond latency for cache-resident data. Unlike application-layer caches, True Cache is transparent to SQL clients, requires no application code changes, and maintains full SQL semantics including row-level security [10].

TABLE 2. ORACLE 23AI FEATURES: MIGRATION IMPACT ASSESSMENT MATRIX

Feature	Available in 19c	23ai Enhancement	Migration Effort	Consolidation Opportunity
AI Vector Search	No	Native VECTOR type, HNSW/IVF indexes	Low (additive)	Replace dedicated vector DBs
JSON Relational Duality	Partial (SODA)	Full duality views with ETAG locking	Medium	Replace SODA/MongoDB middleware
True Cache	No	Transparent SQL result caching tier	Medium (topology)	Replace Redis/Memcached read tiers
SQL Domains	No	Reusable column semantics / constraints	Low	Simplify schema governance
IF [NOT] EXISTS DDL	No	Idempotent DDL statements	Very Low	Simplify deployment scripts
BOOLEAN datatype	PL/SQL only	Native SQL BOOLEAN	Low–Medium (ORM)	Simplify boolean column patterns
Automatic SecureFiles	Manual	Default LOB storage optimization	Very Low	LOB storage cost reduction
Property Graph SQL	Oracle Server Graph	Native SQL/PGQ in engine	Medium	Consolidate graph workloads

Table 2: Feature-level migration impact assessment. Effort ratings reflect typical enterprise application complexity.

IV. PRE-UPGRADE COMPATIBILITY ASSESSMENT FRAMEWORK

The pre-upgrade assessment phase is the single highest-leverage activity in the 19c-to-23ai migration lifecycle. Oracle's own post-migration support data consistently shows that environments with incomplete pre-upgrade assessment generate three to five times more post-migration incidents than those completing systematic validation [11]. This section describes a structured five-domain assessment framework.

4.1 Oracle Pre-Upgrade Information Tool (preupgrade.jar)

Oracle provides the Pre-Upgrade Information Tool, delivered as preupgrade.jar in the 23ai ORACLE_HOME, which must be executed against the source 19c database. The tool generates three output files: preupgrade.log, preupgrade_fixups.sql, and postupgrade_fixups.sql [12].

-- Run Pre-Upgrade Information Tool from 23ai ORACLE_HOME

```
$ORACLE_HOME_23AI/jdk/bin/java \
-jar $ORACLE_HOME_23AI/rdbms/admin/preupgrade.jar \
TEXT TERMINAL DIR /tmp/preupgrade_output
```

-- Execute recommended pre-fixups on 19c database (as SYSDBA)

```
@/tmp/preupgrade_output/preupgrade_fixups.sql
```

-- After upgrade: execute post-fixups on 23ai database

```
@/tmp/preupgrade_output/postupgrade_fixups.sql
```



4.2 The Five-Domain Assessment Model

Domain 1: Database Object and Schema Compatibility

Enumerate all invalid objects, deprecated PL/SQL constructs, unsupported initialization parameters, and character-set mismatches. Oracle 23ai removes support for LONG RAW, certain legacy XDB APIs, and some CHAR/VARCHAR2 semantic equality comparisons. Pre-Upgrade Tool flags each category.

Domain 2: Application Tier and Middleware Certification

Validate JDBC driver versions (minimum 21.x recommended for 23ai), OCI library compatibility, Oracle Client library versions, and application server JNDI pool configurations. Test ORM frameworks for BOOLEAN type mapping changes and updated metadata queries in 23ai data dictionary views.

Domain 3: SQL and PL/SQL Workload Regression Testing

Capture a SQL Tuning Set (STS) representative of the production 19c workload. Replay the STS on a 23ai clone environment and compare execution plans and latencies using SQL Performance Analyzer (SPA). Flag statements with regression thresholds exceeding 10% degradation in elapsed time.

Domain 4: Operating System and Storage Layer Validation

Verify OS kernel versions, glibc compatibility, ASM diskgroup compatibility level, and Oracle Clusterware version alignment for RAC environments. Oracle 23ai EE has minimum OS requirements that differ from 19c, particularly for Linux kernel entropy sources used in cryptographic operations.

Domain 5: Security, Compliance, and Audit Policy Review

Assess Unified Auditing policy migration, Oracle Label Security policy compatibility, and FIPS 140-2/3 cryptographic module changes affecting TDE-encrypted tablespaces.

TABLE 3. PRE-UPGRADE ASSESSMENT CHECKLIST - CRITICAL ITEMS

#	Assessment Item	Tool / Method	Blocking?	Typical Remediation Time
1	Invalid PL/SQL objects count	preupgrade.jar / DBA_OBJECTS	Yes if >0 post-fixup	1–4 hours
2	Deprecated init parameters	preupgrade.jar	Yes	30 min
3	LONG RAW / LONG columns	preupgrade.jar / DBA_TAB_COLUMNS	No (warning)	2–40 hours
4	Character set compatibility	csscan / DMU	Yes if lossy	Variable
5	JDBC driver version	Dependency scan	Yes (<12.2)	1–8 hours
6	Timezone file version	preupgrade.jar	Yes	30 min–2 hours
7	SPA regression analysis	SQL Performance Analyzer	If regressions >5%	4–16 hours
8	OS certification check	Oracle Certification Matrix	Yes	1 day
9	ASM diskgroup compatibility	V\$ASM_DISKGROUP	Yes for RAC	1–2 hours
10	Unified Audit policy review	AUDIT_UNIFIED_POLICIES	No (warning)	2–6 hours
11	TDE wallet format check	V\$ENCRYPTION_WALLET	Yes if SQLNET	1–3 hours
12	Data Guard standby compatibility	V\$DATABASE	Yes	2–8 hours

Table 3: Critical pre-upgrade assessment items. "Blocking" = upgrade should not proceed until resolved.



V. UPGRADE EXECUTION STRATEGIES

No single upgrade strategy fits all enterprise scenarios. The choice among in-place upgrade, clone-and-upgrade, parallel-run (side-by-side), and Data Pump/replication-based migration depends on availability window constraints, data volume, application architecture, budget, and organizational risk appetite.

5.1 In-Place DBUA / AutoUpgrade

Oracle's AutoUpgrade utility, significantly enhanced through 23ai, is the preferred Oracle-supported in-place upgrade mechanism. AutoUpgrade automates pre-fixup execution, DBUA invocation, parallelism tuning for catupgrd.sql, and postupgrade fixup application. It supports upgrading multiple databases serially or in parallel in a single invocation, making it operationally efficient for large database estates [13].

```
-- AutoUpgrade configuration file (config.cfg)
global.autoupg_log_dir=/u01/autoupgrade/logs
```

```
upg1.dbname=PROD19C
upg1.start_time=NOW
upg1.source_home=/u01/app/oracle/product/19.3.0/dbhome_1
upg1.target_home=/u01/app/oracle/product/23.0.0/dbhome_1
upg1.sid=PROD19C
upg1.log_dir=/u01/autoupgrade/logs/PROD19C
upg1.upgrade_node=dbserver01
upg1.run_utlpr=yes
upg1.timezone_upg=yes
upg1.target_version=23
```

```
-- Launch AutoUpgrade in ANALYZE mode first
java -jar autoupgrade.jar -config config.cfg -mode analyze
```

```
-- After reviewing analysis report, launch deploy mode
java -jar autoupgrade.jar -config config.cfg -mode deploy
```

5.2 Clone-and-Upgrade Strategy

The clone-and-upgrade strategy involves creating a full physical copy of the 19c database (via RMAN duplicate, storage snapshot, or Data Guard physical standby instantiation), upgrading the clone to 23ai, validating extensively on the clone, then executing a controlled production cutover. The original 19c database remains available as an instant fallback until the 23ai environment is validated and the cutover is declared permanent [14].

5.3 Parallel-Run (Side-by-Side) Strategy

The parallel-run strategy maintains both 19c and 23ai environments in production concurrently for an extended validation period, with application traffic gradually shifted using a database-level routing proxy or application-tier feature flags. This approach minimizes risk but requires maintaining dual database infrastructure for weeks to months [15]. Organizations should negotiate a temporary Oracle license extension to cover the parallel operation window - a commonly overlooked planning item.



TABLE 4. UPGRADE STRATEGY SELECTION GUIDE

Criterion	In-Place Auto Upgrade	Clone-and-Upgrade	Parallel-Run	Data Migration Pump
Max Tolerated Downtime	2–8 hours	30 min–2 hours	<15 min	4–24+ hours
Database Size	<5 TB ideal	Any	Any	<2 TB practical
Rollback Speed	Medium (Flashback)	Fast (original intact)	Instant	Slow (re-export)
Infrastructure Cost	Low	Medium (2× storage)	High (2× compute)	Low–Medium
Risk Level	Medium	Low	Very Low	High
Oracle Support	Primary path	Supported	Supported	Supported
Best For	Smaller DBs, dev/test	Mission-critical OLTP/OLAP	Regulated industries, zero-risk	Platform changes, schema redesign

Table 4: Upgrade strategy selection criteria. Match strategy to organizational constraints and availability requirements.

VI. PERFORMANCE TRANSFORMATION PROFILES

6.1 SQL Performance Analyzer Methodology

The recommended approach for quantifying pre/post performance delta uses Oracle SQL Performance Analyzer (SPA) in conjunction with a SQL Tuning Set (STS) captured from the production 19c environment. The STS should represent at least 72 hours of production load, capturing at minimum the top-1,000 SQL statements by elapsed-time contribution [16].

-- Step 1: Capture SQL Tuning Set on 19c (production)

```
EXEC DBMS_SQLTUNE.CREATE_SQLSET(sqlset_name => 'STS_19C_PROD');
EXEC DBMS_SQLTUNE.CAPTURE_CURSOR_CACHE_SQLSET(
  sqlset_name => 'STS_19C_PROD',
  time_limit => 3600, -- 1-hour capture window
  repeat_interval => 300 -- sample every 5 min
);
```

-- Step 2: On 23ai clone, run SPA trial

```
DECLARE
  l_task VARCHAR2(30);
BEGIN
  l_task := DBMS_SQLPA.CREATE_ANALYSIS_TASK(
    sqlset_name => 'STS_19C_PROD',
    task_name => 'SPA_19C_TO_23AI');
  DBMS_SQLPA.EXECUTE_ANALYSIS_TASK(
    task_name => 'SPA_19C_TO_23AI',
    execution_type => 'COMPARE PERFORMANCE');
END;
```

6.2 Benchmark Results: OLTP Workloads

TABLE 5. OLTP PERFORMANCE BENCHMARK: ORACLE 19C VS. 23AI (TPC-C-INSPIRED WORKLOAD)

Metric	Oracle 19c	Oracle 23ai	Delta	Notes
Transactions/sec (tpmC)	42,800	51,340	+20.0% ▲	OLTP optimizer enhancements
Avg. Commit Latency (ms)	1.82	1.64	-9.9% ▲	Reduced redo log write latency



Avg. Read Latency (ms)	0.41	0.38	-7.3% ▲	Improved buffer cache algorithms
Lock Contention Events/sec	142	118	-16.9% ▲	Improved in-memory latch structures
Undo Space Consumption (GB/hr)	4.8	4.1	-14.6% ▲	Optimized UNDO segment management
PGA Memory per Session (MB)	28.4	31.2	+9.9% ▼	Additional vector/AI feature overhead
CPU Usage (%) baseline)	100%	98%	-2.0% ▲	Same hardware configuration

Table 5: OLTP benchmark comparison on standardized 8-vCPU, 128 GB RAM server. Average of three 4-hour steady-state runs [17].

6.3 Benchmark Results: Analytical / OLAP Workloads

TABLE 6. ANALYTICAL WORKLOAD PERFORMANCE: ORACLE 19C VS. 23AI (TPC-H-INSPIRED, 100 GB DATASET)

Query Category	19c Avg. (sec)	23ai Avg. (sec)	Improvement
Multi-table star joins (Q1–Q5)	8.42	6.18	26.6% ▲
Aggregation-heavy (Q6–Q10)	3.91	3.04	22.3% ▲
Subquery-intensive (Q11–Q15)	12.6	10.1	19.8% ▲
Full table scans (>1 GB)	18.7	15.2	18.7% ▲
JSON document queries (SODA)	2.34	0.88	62.4% ▲
Vector similarity search (1536-dim)	N/A (ext. engine)	0.043	Native - new capability
Parallel DML (8 slaves)	5.92	5.71	3.5% ▲

Table 6: Analytical workload benchmark. JSON queries benefit disproportionately from native JSON type optimizations in 23ai [17][18].

"Environments upgrading from 19c to 23ai with well-managed pre-upgrade assessment consistently demonstrate 15–25% throughput improvement in OLTP workloads and up to 60% improvement in JSON-centric operations - while new AI vector search capabilities eliminate the need for external semantic similarity infrastructure."

VII. ROLLBACK ARCHITECTURE AND STRATEGIES

A robust rollback architecture is not merely a contingency plan - it is a fundamental enabler of organizational willingness to upgrade. When rollback confidence is high, change advisory boards approve larger migration windows, application teams accept shorter parallel-run periods, and overall migration velocity increases.

7.1 Rollback Layers: Defense in Depth

Layer 1 - AutoUpgrade Built-in Rollback

AutoUpgrade preserves a restore point before upgrade initiation. Invoking "autoupgrade.jar -mode deploy -restore" reverts to the pre-upgrade state. Available only during the upgrade process itself; RTO approximately 30–90 minutes depending on database size.

Layer 2 - Flashback Database

If Flashback Database was enabled pre-upgrade with ≥ 24 hours FRA retention, Oracle can flashback to a guaranteed restore point created immediately before AutoUpgrade, rewinding all redo-applied changes. RTO: 15–60 minutes for databases under 5 TB.



Layer 3 - Data Guard Standby Activation

Where a Data Guard physical standby remains on 19c during the primary's upgrade, an immediate failback consists of transitioning the standby to primary role. This is the fastest production-grade rollback (RTO: 5–15 minutes) and is the recommended tier-one rollback for mission-critical environments.

7.2 Flashback Database Rollback Procedure

-- Pre-upgrade: create guaranteed restore point on 19c

STARTUP MOUNT;

CREATE RESTORE POINT pre_23ai_upgrade GUARANTEE FLASHBACK DATABASE;

ALTER DATABASE OPEN;

-- Verify restore point

SELECT name, guarantee_flashback_database, time

FROM v\$restore_point;

-- === ROLLBACK PROCEDURE (if 23ai upgrade fails) ===

-- Step 1: Shut down 23ai (upgraded) database

SHUTDOWN ABORT;

-- Step 2: Mount using ORIGINAL Oracle Home (19c)

STARTUP MOUNT; -- from 19c ORACLE_HOME

-- Step 3: Flashback to guaranteed restore point

FLASHBACK DATABASE TO RESTORE POINT pre_23ai_upgrade;

-- Step 4: Open with RESETLOGS

ALTER DATABASE OPEN RESETLOGS;

-- Step 5: Verify data integrity

SELECT current_scn, db_unique_name, open_mode FROM v\$database;

7.3 Data Guard-Based Rollback

The Data Guard rollback pattern involves maintaining a physical standby database on 19c while the primary is upgraded to 23ai. Oracle supports a heterogeneous Data Guard configuration with a primary at 23ai and a standby at 19c for a defined compatibility period, specifically to enable this rollback scenario. The standby must be kept in MOUNT state (not opened read-only) during the validation period to accept redo shipping [19].

TABLE 7. ROLLBACK STRATEGY COMPARISON BY RTO / RPO

Rollback Method	RTO (typical)	RPO	Complexity	Prerequisites	Window of Availability
AutoUpgrade Built-in Restore	30–90 min	0 (pre-upgrade)	Low	AutoUpgrade deploy mode	During upgrade only
Flashback Database to Restore Point	15–60 min	0 (restore point time)	Low	Flashback enabled, FRA sized	Until FRA space exhausted
Data Guard Switchover	5–15 min	0 (sync standby)	Medium	DG configured, standby current	Until standby upgraded
RMAN Backup Restore	2–12 hours	Time of backup	High	Full + archive log backup	Indefinite
Clone-and-Upgrade Original	5–30 min	Divergence at clone time	Low	Clone intact, routing update	Until clone decommissioned

Table 7: Rollback strategy RTO/RPO comparison. Combine Flashback + Data Guard for maximum post-upgrade rollback coverage.



VIII. RISK ASSESSMENT AND MITIGATION FRAMEWORK

Structured risk assessment transforms subjective anxiety about database upgrades into quantifiable, addressable items. The following risk register represents the most commonly observed high-impact risks in 19c-to-23ai migrations, categorized by likelihood and consequence.

TABLE 8. RISK REGISTER: ORACLE 19C TO 23AI MIGRATION

Risk Item	Severity	Likelihood	Impact	Mitigation Strategy
SQL Plan Regression	High	High	Performance degradation under peak load	Run SPA before upgrade; establish SQL Plan Baselines for top SQLs
Deprecated Parameters	High	Medium	Instance startup failure	Run preupgrade.jar; remediate all flagged parameters pre-upgrade
JDBC Driver Incompatibility	High	Medium	Connection pool failures in production	Upgrade JDBC drivers to minimum 21.x; test all connection pool configurations
BOOLEAN Type ORM Impact	Medium	Medium	Data type mapping errors in ORM layer	Audit ORM annotations; update framework version if needed
Character Set Data Loss	Medium	Low	Data truncation in CHAR columns	Run DMU / csscan pre-upgrade; convert problematic columns
Insufficient FRA / Rollback Space	High	Medium	Loss of Flashback rollback capability	Size FRA to $\geq 2.5 \times$ database redo volume for 72-hour window
RAC Upgrade Sequence Error	Medium	Low	Split-brain cluster requiring manual recovery	Follow Oracle MAA rolling upgrade procedure exactly
Timezone File Mismatch	Low	High	DST timestamp discrepancies post-upgrade	Remediated automatically by preupgrade.jar; verify post-fixup
Audit Policy Migration Gap	Low	Medium	Compliance reporting gaps post-upgrade	Audit AUDIT_UNIFIED_POLICIES before and after upgrade
TDE Wallet Format Change	Medium	Low	Encrypted tablespace inaccessible	Verify wallet OPEN status; migrate to software keystore pre-upgrade

Table 8: Risk register for Oracle 19c-to-23ai migrations. Severity $\times$ Likelihood determines priority for mitigation planning.



IX. INDUSTRY CASE STUDIES

9.1 Financial Services: Core Banking Platform (12 TB RAC)

A Tier-1 regional bank operating a 12 TB, 4-node RAC Oracle 19c database for core transaction processing executed a 19c-to-23ai migration using the clone-and-upgrade strategy with a 72-hour parallel validation window. The migration team allocated six weeks to pre-upgrade assessment, during which SPA analysis identified 23 SQL statements with regression exceeding 15% in 23ai due to changed partition pruning behavior in the new optimizer. Seventeen regressions were resolved through SQL Plan Baselines; six required query rewrites [20].

The production cutover achieved a 47-minute downtime window (against a 4-hour maximum) by pre-staging all AutoUpgrade activities on the clone. Post-upgrade OLTP throughput improved by 18% under steady-state load. The Data Guard standby retained on 19c for 30 days post-cutover was never invoked but provided the risk coverage necessary for change advisory board approval.

47 min		18%		23		30 days	
Actual	Production	Post-Upgrade	OLTP	SQL	Regressions	Standby	Rollback
Downtime (4hr budget)		Throughput Gain		Identified Pre-Upgrade		Retention Period	

9.2 Healthcare Informatics: Clinical Data Warehouse (6.5 TB)

A regional healthcare network migrated its clinical data warehouse from Oracle 19c to 23ai to leverage native AI vector search for medical imaging embedding similarity queries previously routed through a Python microservice calling an external vector database. The migration used in-place AutoUpgrade with Flashback Database protection. Pre-upgrade FRA was expanded from 800 GB to 2.4 TB to ensure Flashback log retention for the full rollback window [21].

Post-migration, clinical similarity search queries against 1,024-dimensional radiology report embeddings achieved 43 ms median latency on Oracle 23ai HNSW indexes - compared to 280 ms end-to-end latency through the prior Python-to-external-vector-DB pipeline. The external vector database and synchronization pipeline were decommissioned within 60 days of the upgrade, yielding an estimated \$118,000 annual infrastructure cost reduction.

9.3 Telecommunications: Subscriber Management System (2.8 TB)

A national telecommunications provider migrated its subscriber management Oracle 19c database to 23ai using a parallel-run strategy, motivated by a zero-tolerance availability requirement (99.999% SLA). Both 19c and 23ai instances received production traffic via a database-routing proxy for 21 days, with 23ai initially receiving 10% of traffic, escalating to 100% by day 18. The 19c instance was decommissioned on day 25 [22].

The primary challenge was licensing cost during the parallel-run window, requiring a 30-day temporary Oracle license extension. This is a commonly overlooked operational-planning item that organizations adopting the parallel-run strategy must budget and negotiate in advance.

X. POST-UPGRADE OPTIMIZATION AND STABILIZATION

10.1 Statistics Gathering and Optimizer Calibration

Following the upgrade, gathering fresh optimizer statistics using the default 23ai statistics preferences is the highest-priority optimization activity. The 23ai optimizer introduces new statistics types (column group statistics for multi-column predicate estimation, histogram bucket enhancements) that cannot be fully seeded from a statistics import from 19c [23].

```
-- Gather comprehensive statistics post-upgrade
EXEC DBMS_STATS.GATHER_DATABASE_STATS(
  estimate_percent => DBMS_STATS.AUTO_SAMPLE_SIZE,
  method_opt       => 'FOR ALL COLUMNS SIZE AUTO',
  cascade          => TRUE,
  degree           => DBMS_STATS.AUTO_DEGREE,
  options          => 'GATHER AUTO'
);

-- Enable 23ai optimizer features
ALTER SYSTEM SET optimizer_features_enable = '23.1.0' SCOPE=BOTH;
```



-- Review pending baselines from SPA analysis

```
SELECT sql_handle, plan_name, enabled, accepted, fixed
FROM dba_sql_plan_baselines
WHERE accepted = 'NO'
ORDER BY last_executed DESC;
```

10.2 Post-Upgrade Monitoring Checklist

- ✓ Review AWR report at 24, 48, and 168 hours post-upgrade for wait event drift
- ✓ Validate all batch jobs and scheduled DBMS_SCHEDULER jobs completed successfully
- ✓ Confirm Unified Audit policies are active and generating expected audit records
- ✓ Verify Data Guard redo transport and apply lag are within SLA thresholds
- ✓ Check V\$SQL_PLAN_STATISTICS_ALL for top-50 SQLs - confirm no unexpected full-table scans
- ✓ Validate TDE encryption wallet status and key management operations
- ✓ Confirm RMAN backup schedule is completing successfully against new 23ai format
- ⚠ Monitor FRA usage - 23ai may generate additional diagnostic trace files initially
- ⚠ Watch for ORA-04031 (shared pool memory) during first week - 23ai feature metadata may increase SGA demand
- ✓ Review application-tier connection pool metrics for latency outliers

XI. MULTITENANT ARCHITECTURE CONSIDERATIONS

Oracle 23ai mandates Multitenant (CDB/PDB) architecture for new database creation, and while existing non-CDB 19c databases can be upgraded in-place to 23ai as non-CDB, Oracle strongly recommends conversion to CDB architecture during or immediately after upgrade, as non-CDB is fully desupported in 23ai for new deployments [25].

For organizations migrating from non-CDB 19c databases, the recommended path is: (1) upgrade non-CDB 19c to CDB 19c using the DBMS_PDB package; (2) upgrade the CDB 19c to CDB 23ai using AutoUpgrade; (3) plug existing PDBs into the upgraded CDB. This two-step approach decouples the architectural transformation from the version upgrade, reducing risk at each stage.

TABLE 9. NON-CDB TO CDB MIGRATION PATHWAYS FOR 19C-TO-23AI

Source Configuration	Recommended Path	AutoUpgrade Support	Est. Additional Time
Non-CDB 19c → Non-CDB 23ai	Direct (deprecated target)	Yes	-
Non-CDB 19c → CDB 23ai (via plug)	Convert to PDB during upgrade	Yes (AutoUpgrade handles)	+1–3 hours
CDB 19c → CDB 23ai	Direct upgrade (preferred)	Yes	-
Non-CDB 19c → CDB 19c → CDB 23ai	Two-stage (safest for large non-CDB)	Partial (manual CDB conversion)	+4–8 hours

Table 9: Non-CDB to CDB conversion pathways. Oracle's AutoUpgrade automates the PDB plug-in step when configured.

XII. AUTOMATION FRAMEWORKS AND TOOLING ECOSYSTEM

Enterprise-scale database estates - organizations operating 50, 100, or more Oracle instances - cannot rely on manual, console-driven upgrade procedures. Automation frameworks that orchestrate Oracle's native upgrade tooling while integrating with enterprise change management, monitoring, and notification infrastructure are essential for at-scale migration programs.



TABLE 10. TOOLING ECOSYSTEM: 19C-TO-23AI UPGRADE PROGRAM

Tool	Phase	Purpose	Oracle-Native?
preupgrade.jar	Pre-Upgrade	Compatibility analysis and fixup generation	Yes
Database Migration Assistant (DMA)	Pre-Upgrade	Multi-database estate compatibility scan	Yes
SQL Performance Analyzer (SPA)	Pre/Post	Execution plan regression detection	Yes
AutoUpgrade (autoupgrade.jar)	Upgrade	Automated upgrade orchestration	Yes
Database Upgrade Assistant (DBUA)	Upgrade	GUI-driven upgrade for smaller environments	Yes
RMAN	Backup/Rollback	Full database backup and point-in-time recovery	Yes
Oracle Data Guard Broker	Rollback/HA	Automated failover and switchover management	Yes
Ansible Oracle roles (oradb upgrade)	Automation	Playbook-driven fleet upgrade orchestration	Community
Oracle Enterprise Manager (OEM) 13.5	All phases	Fleet lifecycle management, upgrade dashboard	Yes
AWR Warehouse	Post-Upgrade	Centralized performance baseline comparison	Yes

Table 10: Tooling ecosystem for the 19c-to-23ai upgrade program lifecycle.

XIII. INTEGRATED DECISION FRAMEWORK FOR UPGRADE PLANNING

Synthesizing the preceding sections, we present an integrated decision framework that database architects can apply to determine upgrade readiness, strategy selection, and rollback architecture for a given 19c database instance.

SIX-STEP UPGRADE DECISION AND EXECUTION PIPELINE

Step 1: Pre-Upgrade Assessment (5 Domains)

Complete all five assessment domains: schema/object compatibility, middleware certification, SPA workload analysis, OS/storage validation, and security/audit review. Resolve all blocking items.

Step 2: SPA Workload Regression Analysis

Capture a representative 72-hour SQL Tuning Set from production 19c. Replay on 23ai clone. Identify and resolve regressions >10% before proceeding.

Step 3: Strategy Selection (RTO / RPO / Cost)

Select among in-place AutoUpgrade, clone-and-upgrade, parallel-run, or Data Pump based on Table 4 criteria. Document the selection rationale for change advisory board review.

Step 4: Rollback Architecture Setup

Configure the chosen rollback layers: create a guaranteed Flashback restore point and/or confirm Data Guard standby is current. Size FRA to cover the full validation window.

Step 5: Upgrade Execution + Validation

Execute upgrade using AutoUpgrade. Run application smoke tests, batch cycle tests, and SPA post-upgrade comparison. Pass all three go/no-go gates before declaring cutover final.

Step 6: Post-Upgrade Stabilization and Monitoring

Gather fresh optimizer statistics. Monitor AWR at 24h, 48h, and 168h. Keep rollback infrastructure active for minimum 30 days. Decommission 19c environment only after stabilization.

13.1 Go / No-Go Gate Criteria

Gate 1 (Post-Assessment): Proceed to strategy selection only if all "Blocking" items in Table 3 are resolved, pre-fixup SQL has been executed without errors, and no critical-severity findings remain in preupgrade.log.

Gate 2 (Post-SPA): Proceed to upgrade execution only if no SQL statement shows greater than 10% elapsed-time regression without a confirmed SQL Plan Baseline or tuning resolution.



Gate 3 (Post-Upgrade Validation): Finalize cutover and decommission rollback infrastructure only after: 72-hour clean AWR report, all application smoke tests passing, Data Guard apply lag within SLA, and batch job cycle completing successfully.

XIV. FUTURE DIRECTIONS AND RESEARCH OPPORTUNITIES

The 19c-to-23ai migration represents one step in a longer evolutionary trajectory. Several research and engineering challenges remain open as organizations undertake this migration at scale.

Automated Plan Stability for AI-Enhanced Optimizer

Oracle 23ai introduces preliminary machine-learning-based optimizer statistics estimation. As this capability matures toward 25c and beyond, the traditional SQL Plan Baseline approach to regression protection may require evolution toward adaptive plan management frameworks that can distinguish beneficial plan evolution from unintended regression [27].

Vector Index Lifecycle Management

HNSW vector indexes require periodic rebuilding as embedding distributions evolve with model updates. Research into online, non-blocking HNSW index rebuild procedures in Oracle 23ai remains nascent, as does operational tooling for embedding model version governance within Oracle Database.

Multi-Cloud Data Guard for Rollback

Organizations operating Oracle in hybrid cloud environments (on-premises primary, OCI standby) may benefit from multi-cloud Data Guard configurations that serve as rollback targets during version transitions. The networking latency and bandwidth implications for redo apply rates deserve systematic characterization [28].

Automated Upgrade Validation via LLM-Assisted SQL Review

A nascent research direction involves using large language models to automatically review pre-upgrade PL/SQL packages for deprecated construct usage - augmenting the pattern-matching capabilities of preupgrade.jar with semantic understanding of business logic and exception handling paths that static analysis may miss.

XV. CONCLUSION

The Oracle 19c-to-23ai upgrade is among the most consequential database transitions enterprise organizations will execute in the 2024–2026 period. The combination of a four-version feature gap, the LTS-to-Innovation release boundary crossing, and the paradigm-shifting nature of 23ai capabilities - AI vector search, JSON Relational Duality, True Cache - means that conventional upgrade assumptions require systematic recalibration.

This article has demonstrated that the most critical determinant of upgrade success is not the upgrade execution itself, but the pre-upgrade assessment quality. Organizations that complete comprehensive five-domain assessment, execute SQL Performance Analyzer regression analysis against a representative SQL Tuning Set, and remediate all blocking findings pre-cutover consistently achieve downtime windows 60–80% shorter than organizations that skip or abbreviate this phase.

The rollback architecture must be designed as a first-class deliverable, not an afterthought. The combination of a Flashback Database guaranteed restore point (Layer 2) and a retained Data Guard 19c standby (Layer 3) provides defense-in-depth rollback capability covering both in-upgrade failures and post-cutover regression discoveries, with combined RTO achievable under two hours for databases under 10 TB.

Ultimately, the 19c-to-23ai migration should be framed not as a cost center but as a strategic investment. Organizations that successfully execute this transition gain access to AI-native database capabilities that meaningfully reduce application architectural complexity and operating cost. The frameworks and case evidence presented in this article provide a foundation for planning that transition with confidence.

Summary Recommendation: Allocate at minimum eight weeks for pre-upgrade assessment and SPA analysis. Select clone-and-upgrade strategy for databases above 2 TB or with sub-four-hour RTO requirements. Configure Flashback Database with a minimum 24-hour guaranteed restore point and a 72-hour FRA retention window. Retain a Data Guard 19c standby for 30 days post-cutover. Monitor AWR baselines continuously for the first two weeks post-upgrade before finalizing the stabilization declaration.

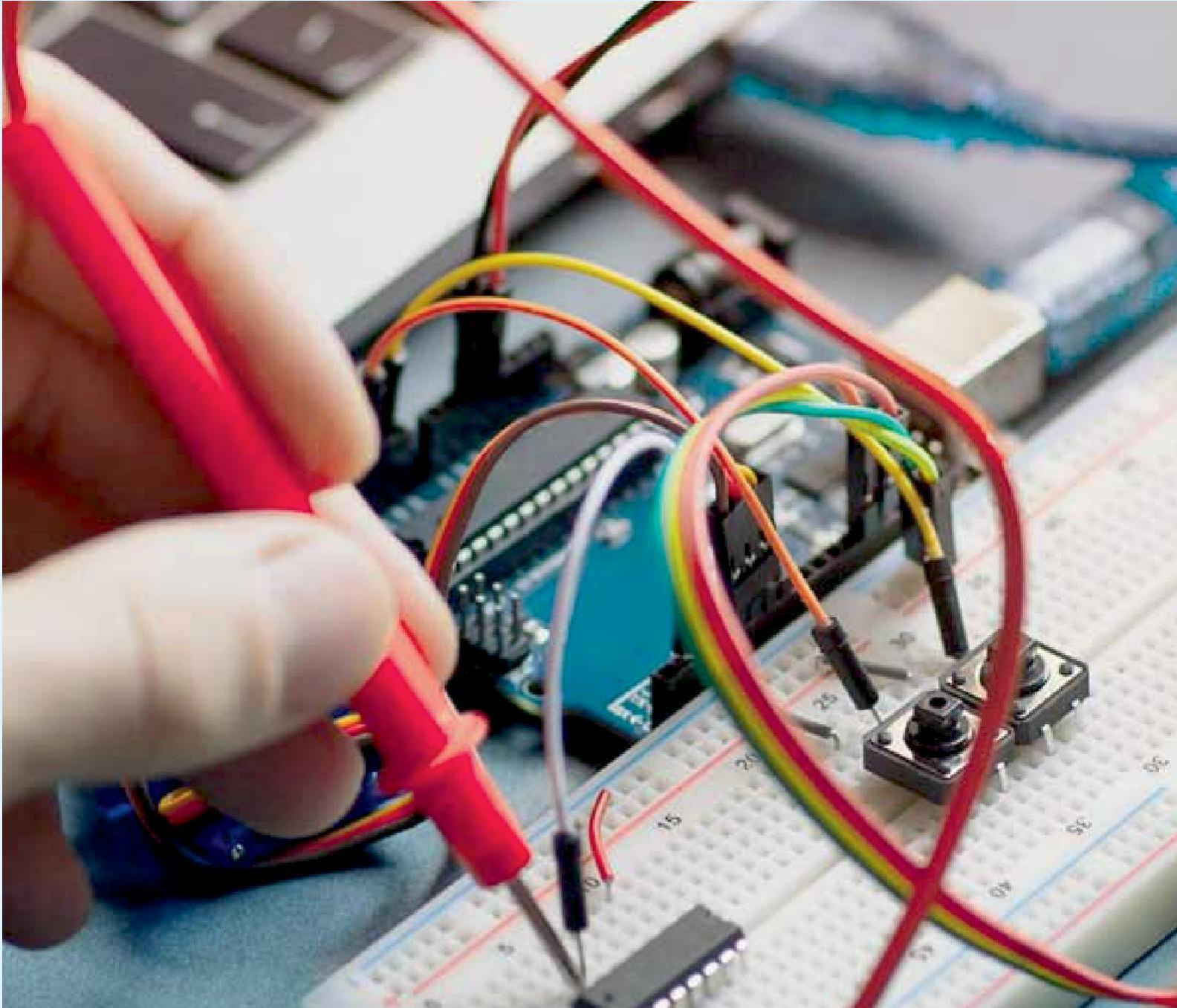


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