8 SQL Processing for Application Developers

This chapter explains what application developers must know about how Oracle Database processes SQL statements.

Topics:

- Description of SQL Statement Processing
- Grouping Operations into Transactions
- Ensuring Repeatable Reads with Read-Only Transactions
- Locking Tables Explicitly
- Using Oracle Lock Management Services (User Locks)
- Using Serializable Transactions for Concurrency Control
- Nonblocking and Blocking DDL Statements
- Autonomous Transactions
- Resuming Execution After Storage Allocation Errors
- Schema Annotations
- Using `IF EXISTS` and `IF NOT EXISTS`

See Also:

Oracle Database Concepts

8.1 Description of SQL Statement Processing

This topic explains what happens during each stage of processing the execution of a SQL statement, using a data manipulation language (DML) statement as an example.

Assume that you are using a Pro*C program to increase the salary for all employees in a department. The program has connected to Oracle Database and you are connected to the HR schema, which owns the `employees` table. You can embed this SQL statement in your program:

```
EXEC SQL UPDATE employees SET salary = 1.10 * salary
  WHERE department_id = :department_id;
```

The program provides a value for the bind variable placeholder `:department_id`, which the SQL statement uses when it runs.

Topics:

- Stages of SQL Statement Processing
- Shared SQL Areas

8.1.1 Stages of SQL Statement Processing

> **Note:**
>
> DML statements use all stages. Transaction management, session management, and system management SQL statements use only `stage 2` and `stage 8`.

1. **Open or create a cursor.**

   A program interface call opens or creates a cursor, in expectation of a SQL statement. Most applications create the cursor implicitly (automatically). Precompiler programs can create the cursor either implicitly or explicitly.

2. **Parse the statement.**

   The user process passes the SQL statement to Oracle Database, which loads a parsed representation of the statement into the shared SQL area. Oracle Database can catch many errors during parsing.

   > **Note:**
   >
   > For a data definition language (DDL) statement, parsing includes data dictionary lookup and execution.

3. **Determine if the statement is a query.**
4. **If the statement is a query, describe its results.**

   > **Note:**
   >
   > This stage is necessary only if the characteristics of the result are unknown; for example, when a user enters the query interactively.

   Oracle Database determines the characteristics (data types, lengths, and names) of the result.

5. **If the statement is a query, define its output.**

   You specify the location, size, and data type of variables defined to receive each fetched value. These variables are called **define variables**. Oracle Database performs data type conversion if necessary.

6. **Bind any variables.**

   Oracle Database has determined the meaning of the SQL statement but does not have enough information to run it. Oracle Database needs values for any bind variable placeholders in the statement. In the example, Oracle Database needs a value for `:department_id`. The process of obtaining these values is called **binding variables**.

   A program must specify the location (memory address) of the value. End users of applications may be unaware that they are specifying values for bind variable placeholders, because the Oracle Database utility can prompt them for the values.

Because the program specifies the location of the value (that is, binds by reference), it need not rebind the variable before rerunning the statement, even if the value changes. Each time Oracle Database runs the statement, it gets the value of the variable from its address.

You must also specify a data type and length for each value (unless they are implied or defaulted) if Oracle Database must perform data type conversion.

7. **(Optional) Parallelize the statement.**

   Oracle Database can parallelize queries and some data definition language (DDL) operations (for example, index creation, creating a table with a subquery, and operations on partitions). Parallelization causes multiple server processes to perform the work of the SQL statement so that it can complete faster.

8. **Run the statement.**

   Oracle Database runs the statement. If the statement is a query or an `INSERT` statement, the database locks no rows, because no data is changing. If the statement is an `UPDATE` or `DELETE` statement, the database locks all rows that the statement affects, until the next `COMMIT`, `ROLLBACK`, or `SAVEPOINT` for the transaction, thereby ensuring data integrity.

   For some statements, you can specify multiple executions to be performed. This is called **array processing**. Given *n* number of executions, the bind and define locations are assumed to be the beginning of an array of size *n*.

9. **If the statement is a query, fetch its rows.**

   Oracle Database selects rows and, if the query has an `ORDER BY` clause, orders the rows. Each successive fetch retrieves another row of the result set, until the last row has been fetched.

10. **Close the cursor.**

    Oracle Database closes the cursor.

Note:

To rerun a transaction management, session management, or system management SQL statement, use another `EXECUTE` statement.

See Also:

- *Oracle Database Concepts* for information about parsing
- Shared SQL Areas
- *Oracle Database Concepts* for information about the `DEFINE` stage
- *Oracle Call Interface Programmer's Guide*
- *Pro*C/C++ Programmer's Guide*

8.1.2 Shared SQL Areas

Oracle Database automatically detects when applications send similar SQL statements to the database. The SQL area used to process the first occurrence of the statement is *shared*—that is, used for processing subsequent occurrences of that same statement. Therefore, only one shared SQL area exists for a unique statement. Because shared SQL areas are shared memory areas, any Oracle Database process can use a shared SQL area. The sharing of SQL areas reduces memory use on the database server, thereby increasing system throughput.

In determining whether statements are similar or identical, Oracle Database compares both SQL statements issued directly by users and applications and recursive SQL statements issued internally by DDL statements.

See Also:

- *Oracle Database Concepts* for more information about shared SQL areas
- *Oracle Database SQL Tuning Guide* for more information about shared SQL

8.2 Grouping Operations into Transactions

Topics:

- Deciding How to Group Operations in Transactions
- Improving Transaction Performance
- Managing Commit Redo Action
- Determining Transaction Outcome After a Recoverable Outage

See Also:

Oracle Database Concepts for basic information about transactions

8.2.1 Deciding How to Group Operations in Transactions

Typically, deciding how to group operations in transactions is the concern of application developers who use programming interfaces to Oracle Database. When deciding how to group transactions:

- Define transactions such that work is accomplished in logical units and data remains consistent.
- Ensure that data in all referenced tables is in a consistent state before the transaction begins and after it ends.
- Ensure that each transaction consists only of the SQL statements or PL/SQL blocks that comprise one consistent change to the data.

For example, suppose that you write a web application that lets users transfer funds between accounts. The transaction must include the debit to one account, executed by one SQL statement, and the credit to another account, executed by another SQL statement. Both statements must fail or succeed as a unit of work; one statement must not be committed without the other. Do not include unrelated actions, such as a deposit to one account, in the transaction.

8.2.2 Improving Transaction Performance

As an application developer, you must try to improve performance. Consider using these performance enhancement techniques when designing and writing your application:

- For each transaction:
  1. If you can use a single SQL statement, then do so.
  2. If you cannot use a single SQL statement but you can use PL/SQL, then use as little PL/SQL as possible.
  3. If you cannot use PL/SQL (because it cannot do what you must do; for example, read a directory), then use Java.
  4. If you cannot use Java (for example, if it is too slow) or you have existing third-generation language (3GL) code, then use an external C subprogram.
- Establish standards for writing SQL statements so that you can take advantage of shared SQL areas.

  Oracle Database recognizes identical SQL statements and lets them share memory areas, reducing memory usage on the database server and increasing system throughput.
- Collect statistics that Oracle Database can use to implement a cost-based approach to SQL statement optimization, and use additional hints to the optimizer as needed.

  To collect most statistics, use the `DBMS_STATS` package, which lets you collect statistics in parallel, collect global statistics for partitioned objects, and tune your statistics collection in other ways.

  To collect statistics unrelated to the cost-based optimizer (such as information about free list blocks), use the SQL statement `ANALYZE`.
- Before beginning a transaction, invoke `DBMS_APPLICATION_INFO` procedures to record the name of the transaction in the database for later use when tracking its performance with Oracle Trace and the SQL trace facility.
- Increase user productivity and query efficiency by including user-written PL/SQL functions in SQL expressions. For details, see.

See Also:

- *Oracle Database Concepts* for more information about transaction management
- PL/SQL for Application Developers
- Developing Applications with Multiple Programming Languages
- *Oracle Database SQL Language Reference* for more information about hints and `ANALYZE` statement
- *Oracle Database PL/SQL Packages and Types Reference* for more information about `DBMS_STATS` package and `DBMS_APPLICATION_INFO` package
- Invoking Stored PL/SQL Functions from SQL Statements

8.2.3 Managing Commit Redo Action

When a transaction updates Oracle Database, it generates a corresponding redo entry. Oracle Database buffers the redo entry to the redo log until the transaction completes. When the transaction commits, the log writer process (LGWR) writes redo records to disk for the buffered redo entries of all changes in the transaction. By default, Oracle Database writes the redo entries to disk before the call returns to the client. This action causes a latency in the commit, because the application must wait for the redo entries to be persistent on disk.

Oracle Database lets you change the handling of commit redo to fit the needs of your application. If your application requires very high transaction throughput and you are willing to trade commit durability for lower commit latency, then you can change the default `COMMIT` options so that the application need not wait for the database to write data to the online redo logs.

Table 8-1 describes the `COMMIT` options.

Caution:

With the `NOWAIT` option, a failure that occurs after the commit message is received, but before the redo log records are written, can falsely indicate to a transaction that its changes are persistent.

Table 8-1 COMMIT Statement Options

Option	Effect
`WAIT` (default)	Ensures that the `COMMIT` statement returns only after the corresponding redo information is persistent in the online redo log. When the client receives a successful return from this `COMMIT` statement, the transaction has been committed to durable media. A failure that occurs after a successful write to the log might prevent the success message from returning to the client, in which case the client cannot tell whether the transaction committed.
`NOWAIT` (alternative to `WAIT`)	The `COMMIT` statement returns to the client regardless of whether the write to the redo log has completed. This behavior can increase transaction throughput.
`BATCH` (alternative to `IMMEDIATE`)	Buffers the redo information to the redo log with concurrently running transactions. After collecting sufficient redo information, initiates a disk write to the redo log. This behavior is called **group commit**, because it writes redo information for multiple transactions to the log in a single I/O operation.
`IMMEDIATE` (default)	LGWR writes the transaction redo information to the log. Because this operation option forces a disk I/O, it can reduce transaction throughput.

To change the `COMMIT` options, use either the `COMMIT` statement or the appropriate initialization parameter.

Note:

You cannot change the default `IMMEDIATE` and `WAIT` action for distributed transactions.

If your application uses Oracle Call Interface (OCI), then you can modify redo action by setting these flags in the `OCITransCommit` function in your application:

- `OCI_TRANS_WRITEWAIT`
- `OCI_TRANS_WRITENOWAIT`
- `OCI_TRANS_WRITEBATCH`
- `OCI_TRANS_WRITEIMMED`

Caution:

`OCI_TRANS_WRITENOWAIT` can cause silent transaction loss with shutdown termination, startup force, and any instance or node failure. On an Oracle RAC system, asynchronously committed changes might not be immediately available to read on other instances.

The specification of the `NOWAIT` and `BATCH` options has a small window of vulnerability in which Oracle Database can roll back a transaction that your application views as committed. Your application must be able to tolerate these scenarios:

- The database host fails, which causes the database to lose redo entries that were buffered but not yet written to the online redo logs.
- A file I/O problem prevents LGWR from writing buffered redo entries to disk. If the redo logs are not multiplexed, then the commit is lost.

See Also:

- *Oracle Call Interface Programmer's Guide* for information about the `OCITransCommit` function
- *Oracle Database SQL Language Reference*
- *Oracle Database Reference* for information about initialization parameters

8.2.4 Determining Transaction Outcome After a Recoverable Outage

A **recoverable outage** is a system, hardware, communication, or storage failure that breaks the connection between your application (the client) and Oracle Database (the server). After an outage, your application receives a disconnection error message. The transaction that was running when the connection broke is the **in-flight transaction**, which may or may not have been committed or run to completion.

To recover from the outage, your application must determine the outcome of the in-flight transaction—whether it was committed and whether it made its intended session state changes. If the transaction was not committed, then the application can either resubmit the transaction or return the uncommitted status to the end user. If the transaction was committed, then the application can return the committed status, rather than the disconnection error, to the end user. If the transaction was both committed and completed, then the application may be able to continue by taking a new session and re-establishing the session state.

The Oracle Database feature that provides your application with the outcome of the in-flight transaction and can be used to ensure that it is not duplicated is Transaction Guard, and its application program interface (API) is the PL/SQL procedure `DBMS_APP_CONT.GET_LTXID_OUTCOME`.

Topics:

- Understanding Transaction Guard
- Understanding DBMS_APP_CONT.GET_LTXID_OUTCOME
- Using Transaction Guard

8.2.4.1 Understanding Transaction Guard

Transaction Guard is an Oracle Database tool that you can use to provide your application with the outcome of the in-flight transaction after an outage. The application can use Transaction Guard to provide the end user with a known outcome after an outage—committed or not committed—and, optionally, to replay the transaction if it did not commit and the states are correct.

Transaction Guard provides the transaction outcome through its API, the PL/SQL procedure `DBMS_APP_CONT.GET_LTXID_OUTCOME`.

Transaction Guard relies on the **logical transaction identifier (LTXID)**, a globally unique identifier that identifies the last in-flight transaction on a session that failed. The database records the LTXID when the transaction is committed, and returns a new LTXID to the client with the commit message (for each client round trip). The client driver always holds the LTXID that will be used at the next `COMMIT`.

Note:

- Use Transaction Guard only to find the outcome of a session that failed due to a recoverable error, to replace the communication error with the real outcome.
- Do not use Transaction Guard on your own session.
- Do not use Transaction Guard on a live session.

  To stop a live session, use `ALTER SYSTEM KILL SESSION IMMEDIATE` at the local or remote instance.

See Also:

Understanding DBMS_APP_CONT.GET_LTXID_OUTCOME

8.2.4.1.1 How Transaction Guard Uses the LTXID

Transaction Guard uses the LTXID as follows:

- While a transaction is running, both Oracle Database (the server) and your application (the client) hold the LTXID to be used at the next `COMMIT`.
- When the transaction is committed, Oracle Database records the LTXID with the transaction. If the LTXID has already been committed or has been blocked, then the database raises error, preventing duplication of the transaction.
- The LTXID persists in Oracle Database for the time specified by the `RETENTION_TIMEOUT` parameter. The default is 24 hours. To change this value:
  - When running Real Application Clusters, use Server Control Utility (SRVCTL).
  - When not using Real Application Clusters, use the `DBMS_SERVICE` package.

  If the transaction is remote or distributed, then its LTXID persists in the local database.

  The LTXID is transferred to Data Guard and Active Data Guard in the standard redo apply.
- After a recoverable error:
  - If the transaction has not been committed, then Oracle Database blocks its LTXID to ensure that an earlier in-flight transaction with the same LTXID cannot be committed.

    This behavior allows the application to return the uncommitted result to the user, who can then decide what to do, and also allows the application to safely replay the application if desirable.
  - If the transaction has been committed, then the application can return this result to the end user, and if the state is correct, the application may be able to continue.
- If the transaction is rolled back, then Oracle Database reuses its LTXID.

See Also:

- Transaction Guard Coverage, for a list of the sources whose commits Transaction Guard supports
- Transaction Guard Exclusions, for a list of the sources whose commits Transaction Guard does not support
- *Oracle Real Application Clusters Administration and Deployment Guide* for more information about SRVCTL
- *Oracle Database PL/SQL Packages and Types Reference* for more information about `DBMS_SERVICE` package

8.2.4.2 Understanding DBMS_APP_CONT.GET_LTXID_OUTCOME

The PL/SQL procedure `DBMS_APP_CONT.GET_LTXID_OUTCOME` is the API of Transaction Guard. After an outage, your application can reconnect to Oracle Database and then invoke this procedure to determine the outcome of the in-flight transaction.

`DBMS_APP_CONT.GET_LTXID_OUTCOME` has these parameters:

Parameter Name	Data Type	Parameter Mode	Value
`CLIENT_LTXID`	`RAW`	`IN`	LTXID of the in-flight transaction
`COMMITTED`	`BOOLEAN`	`OUT`	`TRUE` if the in-flight transaction was committed, `FALSE` otherwise
`USER_CALL_COMPLETED`	`BOOLEAN`	`OUT`	`TRUE` if the in-flight transaction completed, `FALSE` otherwise

Topics:

- CLIENT_LTXID Parameter
- COMMITTED Parameter
- USER_CALL_COMPLETED Parameter
- Exceptions

See Also:

Oracle Database PL/SQL Packages and Types Reference for more information about `DBMS_APP_CONT.GET_LTXID_OUTCOME`

8.2.4.2.1 CLIENT_LTXID Parameter

Before your application (the client) can invoke `DBMS_APP_CONT.GET_LTXID_OUTCOME` with the LTXID of the in-flight transaction, it must get the last LTXID in use at the client driver by using a client driver. The client driver holds the LTXID of the transaction next to be committed. In this case, the LTXID is for the in-flight transaction at the time of the outage. Use `getLTXID` for JDBC-Thin driver, `LogicalTransactionId` for ODP.NET, and `OCI_ATTR_GET` with LTXID for OCI and OCCI.

The JDBC-Thin driver also provides a callback that is triggered each time the LTXID at the client driver changes. The callback can be used to maintain the current LTXID to be used. The callback is particularly useful for application servers and applications that must block repeated executions.

Note:

Your application must get the LTXID immediately before passing it to `DBMS_APP_CONT.GET_LTXID_OUTCOME`. Getting the LTXID in advance could lead to passing an earlier LTXID to `DBMS_APP_CONT.GET_LTXID_OUTCOME`, causing the request to be rejected.

See Also:

- *Oracle Database JDBC Developer’s Guide*
- *Oracle Call Interface Programmer's Guide*
- *Oracle Data Provider for .NET Developer's Guide for Microsoft Windows*

8.2.4.2.2 COMMITTED Parameter

After `DBMS_APP_CONT.GET_LTXID_OUTCOME` returns control to your application, your application can check the value of the actual parameter that corresponds to the formal parameter `COMMITTED` to determine whether the in-flight transaction was committed.

If the value of the actual parameter is `TRUE`, then the transaction was committed.

If the value of the actual parameter is `FALSE`, then the transaction was not committed. Therefore, it is safe for the application to return the code `UNCOMMITTED` to the end user or use it to replay the transaction.

To ensure that an earlier session does not commit the transaction after the application returns `UNCOMMITTED`, `DBMS_APP_CONT.GET_LTXID_OUTCOME` blocks the LTXID. Blocking the LTXID allows the end user to make a decision based on the uncommitted status, or the application to replay the transaction, and prevents duplicate transactions.

8.2.4.2.3 USER_CALL_COMPLETED Parameter

Some transactions return information upon completion. For example: A transaction that uses commit on success (auto-commit) might returns the number of affected rows, or for a `SELECT` statement, the rows themselves; a transaction that invokes a PL/SQL subprogram that has `OUT` parameters returns the values of those parameters; and a transaction that invokes a PL/SQL function returns the function value. Also, a transaction that invokes a PL/SQL subprogram might execute a `COMMIT` statement and then do more work.

If your application needs information that the in-flight transaction returns upon completion, or session state changes that the transaction does after committing its database changes, then your application must determine whether the in-flight transaction completed, which it can do by checking the value of the actual parameter that corresponds to the formal parameter `USER_CALL_COMPLETED`.

If the value of the actual parameter is `TRUE`, then the transaction completed, and your application has the information and work that it must continue.

If the value of the actual parameter is `FALSE`, then the call from the client may not have completed. Therefore, your application might not have the information and work that it must continue.

8.2.4.2.4 Exceptions

If your application (the client) and Oracle Database (the server) are no longer synchronized, then the `DBMS_APP_CONT.GET_LTXID_OUTCOME` procedure raises one of these exceptions:

Exception	Explanation
`ORA-14950 - SERVER_AHEAD`	The server is ahead of the client; that is, the LTXID that your application passed to `DBMS_APP_CONT.GET_LTXID_OUTCOME` identifies a transaction that is older than the in-flight transaction. Your application must get the LTXID immediately before passing it to `DBMS_APP_CONT.GET_LTXID_OUTCOME`.
`ORA-14951 - CLIENT_AHEAD`	The client is ahead of the server. Either the server was "flashed back" to an earlier state, was recovered using media recovery, or is a standby database that was opened earlier and has lost data.
`ORA-14906 - SAME_SESSION`	Executing `GET_LTXID_OUTCOME` is not supported on the session that owns the LTXID, because the execution would block further processing on that session.
`ORA-14909 - COMMIT_BLOCKED`	Your session has been blocked from committing by another user with the same username using `GET_LTXID_OUTCOME`. `GET_LTXID_OUTCOME` should be called only on terminated sessions. Blocking a live session is better achieved using `ALTER SYSTEM KILL SESSION IMMEDIATE`. For help, contact your application administrator.
`ORA-14952 GENERAL ERROR`	`DBMS_APP_CONT.GET_LTXID_OUTCOME` cannot determine the outcome of the in-flight transaction. An error occurred during transaction processing, and the error stack shows the error detail.

See Also:

- Using Oracle Flashback Technology
- *Oracle Data Guard Concepts and Administration* for information about media recovery and standby databases

8.2.4.3 Using Transaction Guard

After your application (the client) receives an error message, it must follow these steps to use Transaction Guard:

1. Determine if the error is due to an outage (**recoverable**).

   For instructions, see the documentation for your client driver—`OCI_ATTRIBUTE` for OCI, OCCI, and ODP.NET; `isRecoverable` for JDBC.

2. If the error is recoverable, then use the API of the client driver to get the logical transaction identifier (LTXID) of the in-flight transaction.

   For instructions, see the documentation for your client driver.

3. Reconnect to the database.

   The session that your application acquires can be either new or pooled.

4. Invoke `DBMS_APP_CONT.GET_LTXID_OUTCOME` with the LTXID from step 2.

5. Check the value of the actual parameter that corresponds to the formal parameter `COMMITTED`.

   If the value is `TRUE`, then tell the application that the in-flight transaction was committed. The application can return this result to the user, or continue if the state is correct.

If the value is `FALSE`, then the application can return `UNCOMMITTED` or a similar message to the user so that the user can choose the next step. Optionally, the application can replay the transaction for the user. For example:

a. If necessary, clean up state changes on the client side.
b. Resubmit the in-flight transaction.

If you do not resubmit the in-flight transaction, and the application needs neither information that the in-flight transaction returns upon completion nor work that the transaction does after committing its database changes, then continue. Otherwise, check the value of the actual parameter that corresponds to the formal parameter `USER_CALL_COMPLETED`.

If the value is `TRUE`, then continue.

If the value is `FALSE`, then tell the application user that the application cannot continue.

8.3 Ensuring Repeatable Reads with Read-Only Transactions

By default, Oracle Database guarantees statement-level read consistency, but not transaction-level read consistency. With **statement-level read consistency**, queries in a statement produce consistent data for the duration of the statement, not reflecting changes by other statements. With **transaction-level read consistency** (**repeatable reads**), queries in the transaction produce consistent data for the duration of the transaction, not reflecting changes by other transactions.

To ensure transaction-level read consistency for a transaction that does not include DML statements, specify that the transaction is read-only. The queries in a read-only transaction see only changes committed before the transaction began, so query results are consistent for the duration of the transaction.

A read-only transaction provides transaction-level read consistency without acquiring additional data locks. Therefore, while the read-only transaction is querying data, other transactions can query and update the same data.

A read-only transaction begins with this statement:

```
SET TRANSACTION READ ONLY [ NAME string ];
```

Only DDL statements can precede the `SET TRANSACTION READ ONLY` statement. After the `SET TRANSACTION READ ONLY` statement successfully runs, the transaction can include only `SELECT` (without `FOR UPDATE`), `COMMIT`, `ROLLBACK`, or non-DML statements (such as `SET ROLE`, `ALTER SYSTEM`, and `LOCK TABLE`). A `COMMIT`, `ROLLBACK`, or DDL statement ends the read-only transaction.

See Also:

Oracle Database SQL Language Reference for more information about the `SET TRANSACTION` statement

Long-running queries sometimes fail because undo information required for consistent read (CR) operations is no longer available. This situation occurs when active transactions overwrite committed undo blocks.

Automatic undo management lets your database administrator (DBA) explicitly control how long the database retains undo information, using the parameter `UNDO_RETENTION`. For example, if `UNDO_RETENTION` is 30 minutes, then the database retains all committed undo information for at least 30 minutes, ensuring that all queries running for 30 minutes or less do not encounter the OER error "snapshot too old."

See Also:

- *Oracle Database Concepts* for more information about read consistency
- *Oracle Database Administrator's Guide* for information about long-running queries and resumable space allocation

8.4 Locking Tables Explicitly

Oracle Database has default locking mechanisms that ensure data concurrency, data integrity, and statement-level read consistency. However, you can override these mechanisms by locking tables explicitly. Locking tables explicitly is useful in situations such as these:

- A transaction in your application needs exclusive access to a resource, so that the transaction does not have to wait for other transactions to complete.
- Your application needs transaction-level read consistency (repeatable reads).

To override default locking at the transaction level, use any of these SQL statements:

- `LOCK TABLE`
- `SELECT` with the `FOR UPDATE` clause
- `SET TRANSACTION` with the `READ ONLY` or `ISOLATION LEVEL SERIALIZABLE` option

Locks acquired by these statements are released after the transaction is committed or rolled back.

The initialization parameter `DML_LOCKS` determines the maximum number of DML locks. Although its default value is usually enough, you might need to increase it if you use explicit locks.

Note:

If you override the default locking of Oracle Database at any level, ensure that data integrity is guaranteed, data concurrency is acceptable, and deadlocks are either impossible or appropriately handled.

See Also:

- *Oracle Database Concepts*
- Ensuring Repeatable Reads with Read-Only Transactions
- Using Serializable Transactions for Concurrency Control
- *Oracle Database SQL Language Reference*

Topics:

- Privileges Required to Acquire Table Locks
- Choosing a Locking Strategy
- Letting Oracle Database Control Table Locking
- Explicitly Acquiring Row Locks
- Examples of Concurrency Under Explicit Locking

8.4.1 Privileges Required to Acquire Table Locks

No special privileges are required to acquire any type of table lock on a table in your own schema. To acquire a table lock on a table in another schema, you must have either the `LOCK ANY TABLE` system privilege or any object privilege (for example, `SELECT` or `UPDATE`) for the table.

8.4.2 Choosing a Locking Strategy

A transaction explicitly acquires the specified table locks when a `LOCK TABLE` statement is executed. A `LOCK TABLE` statement explicitly overrides default locking. When a `LOCK TABLE` statement is issued on a view, the underlying base tables are locked. This statement acquires exclusive table locks for the `employees` and `departments` tables on behalf of the containing transaction:

```
LOCK TABLE employees, departments IN EXCLUSIVE MODE NOWAIT;
```

You can specify several tables or views to lock in the same mode; however, only a single lock mode can be specified for each `LOCK TABLE` statement.

Note:

When a table is locked, all rows of the table are locked. No other user can modify the table.

In the `LOCK TABLE` statement, you can also indicate how long you want to wait for the table lock:

- If you do not want to wait, specify either `NOWAIT` or `WAIT 0`.

  You acquire the table lock only if it is immediately available; otherwise, an error notifies you that the lock is unavailable now.
- To wait up to *n* seconds to acquire the table lock, specify `WAIT` *n*, where *n* is greater than 0 and less than or equal to 100000.

If the table lock is still unavailable after *n* seconds, an error notifies you that the lock is unavailable now.

- To wait indefinitely to acquire the lock, specify neither `NOWAIT` nor `WAIT`.

  The database waits indefinitely until the table is available, locks it, and returns control to you. When the database is running DDL statements concurrently with DML statements, a timeout or deadlock can sometimes result. The database detects such timeouts and deadlocks and returns an error.

See Also:

- Explicitly Acquiring Row Locks
- *Oracle Database SQL Language Reference*

Topics:

- When to Lock with ROW SHARE MODE and ROW EXCLUSIVE MODE
- When to Lock with SHARE MODE
- When to Lock with SHARE ROW EXCLUSIVE MODE
- When to Lock with EXCLUSIVE MODE

8.4.2.1 When to Lock with ROW SHARE MODE and ROW EXCLUSIVE MODE

`ROW SHARE MODE` and `ROW EXCLUSIVE MODE` table locks offer the highest degree of concurrency. You might use these locks if:

- Your transaction must prevent another transaction from acquiring an intervening share, share row, or exclusive table lock for a table before your transaction can update that table.

  If another transaction acquires an intervening share, share row, or exclusive table lock, no other transactions can update the table until the locking transaction commits or rolls back.
- Your transaction must prevent a table from being altered or dropped before your transaction can modify that table.

8.4.2.2 When to Lock with SHARE MODE

`SHARE MODE` table locks are rather restrictive data locks. You might use these locks if:

- Your transaction only queries the table, and requires a consistent set of the table data for the duration of the transaction.
- You can hold up other transactions that try to update the locked table, until all transactions that hold `SHARE MODE` locks on the table either commit or roll back.
- Other transactions might acquire concurrent `SHARE MODE` table locks on the same table, also giving them the option of transaction-level read consistency.

> **Caution:**
>
> Your transaction might not update the table later in the same transaction. However, if multiple transactions concurrently hold share table locks for the same table, no transaction can update the table (even if row locks are held as the result of a `SELECT FOR UPDATE` statement). Therefore, if concurrent share table locks on the same table are common, updates cannot proceed and deadlocks are common. In this case, use share row exclusive or exclusive table locks instead.

Scenario: Tables `employees` and `budget_tab` require a consistent set of data in a third table, `departments`. For a given department number, you want to update the information in `employees` and `budget_tab`, and ensure that no members are added to the department between these two transactions.

Solution: Lock the `departments` table in `SHARE MODE`, as shown in Example 8-1. Because the `departments` table is rarely updated, locking it probably does not cause many other transactions to wait long.

Example 8-1 LOCK TABLE with SHARE MODE

```
-- Create and populate table:

DROP TABLE budget_tab;
CREATE TABLE budget_tab (
  sal     NUMBER(8,2),
  deptno  NUMBER(4)
);

INSERT INTO budget_tab (sal, deptno)
  SELECT salary, department_id
  FROM employees;

-- Lock departments and update employees and budget_tab:

LOCK TABLE departments IN SHARE MODE;

UPDATE employees
  SET salary = salary * 1.1
  WHERE department_id IN
    (SELECT department_id FROM departments WHERE location_id = 1700);

UPDATE budget_tab
SET sal = sal * 1.1
WHERE deptno IN
  (SELECT department_id FROM departments WHERE location_id = 1700);

COMMIT;  -- COMMIT releases lock
```

8.4.2.3 When to Lock with SHARE ROW EXCLUSIVE MODE

You might use a `SHARE ROW EXCLUSIVE MODE` table lock if:

- Your transaction requires both transaction-level read consistency for the specified table and the ability to update the locked table.
- You do not care if other transactions acquire explicit row locks (using `SELECT FOR UPDATE`), which might make `UPDATE` and `INSERT` statements in the locking transaction wait and might cause deadlocks.

- You want only a single transaction to have this action.

8.4.2.4 When to Lock with EXCLUSIVE MODE

You might use an `EXCLUSIVE MODE` table if:

- Your transaction requires immediate update access to the locked table. When your transaction holds an exclusive table lock, other transactions cannot lock specific rows in the locked table.
- Your transaction also ensures transaction-level read consistency for the locked table until the transaction is committed or rolled back.
- You are not concerned about low levels of data concurrency, making transactions that request exclusive table locks wait in line to update the table sequentially.

8.4.3 Letting Oracle Database Control Table Locking

If you let Oracle Database control table locking, your application needs less programming logic, but also has less control than if you manage the table locks yourself.

Issuing the statement `SET TRANSACTION ISOLATION LEVEL SERIALIZABLE` or `ALTER SESSION ISOLATION LEVEL SERIALIZABLE` preserves ANSI serializability without changing the underlying locking protocol. This technique gives concurrent access to the table while providing ANSI serializability. Getting table locks greatly reduces concurrency.

See Also:

- *Oracle Database SQL Language Reference* for information about the `SET TRANSACTION` statement
- *Oracle Database SQL Language Reference* for information about the `ALTER SESSION` statements

Change the settings for these parameters only when an instance is shut down. If multiple instances are accessing a single database, then all instances must use the same setting for these parameters.

8.4.4 Explicitly Acquiring Row Locks

You can override default locking with a `SELECT` statement that includes the `FOR UPDATE` clause. This statement acquires exclusive row locks for selected rows (as an `UPDATE` statement does), in anticipation of updating the selected rows in a subsequent statement.

You can use a `SELECT FOR UPDATE` statement to lock a row without changing it. For example, several triggers in Oracle Database PL/SQL Language Reference show how to implement referential integrity. In the `EMP_DEPT_CHECK` trigger, the row that contains the referenced parent key value is locked to guarantee that it remains for the duration of the transaction; if the parent key is updated or deleted, referential integrity is violated.

`SELECT FOR UPDATE` statements are often used by interactive programs that let a user modify fields of one or more specific rows (which might take some time); row locks are acquired so that only a single interactive program user is updating the rows at any given time.

If a `SELECT FOR UPDATE` statement is used when defining a cursor, the rows in the return set are locked when the cursor is opened (before the first fetch) rather than being locked as they are fetched from the cursor. Locks are released only when the transaction that opened the cursor is committed or rolled back, not when the cursor is closed.

Each row in the return set of a `SELECT FOR UPDATE` statement is locked individually; the `SELECT FOR UPDATE` statement waits until the other transaction releases the conflicting row lock. If a `SELECT FOR UPDATE` statement locks many rows in a table, and if the table experiences much update activity, it might be faster to acquire an `EXCLUSIVE` table lock instead.

Note:

The return set for a `SELECT FOR UPDATE` might change while the query is running; for example, if columns selected by the query are updated or rows are deleted after the query started. When this happens, `SELECT FOR UPDATE` acquires locks on the rows that did not change, gets a read-consistent snapshot of the table using these locks, and then restarts the query to acquire the remaining locks.

If your application uses the `SELECT FOR UPDATE` statement and cannot guarantee that a conflicting locking request will not result in user-caused deadlocks—for example, through ensuring that concurrent DML statements on a table never affect the return set of the query of a `SELECT FOR UPDATE` statement—then code the application always to handle such a deadlock (ORA-00060) in an appropriate manner.

By default, the `SELECT FOR UPDATE` statement waits until the requested row lock is acquired. To change this behavior, use the `NOWAIT`, `WAIT`, or `SKIP LOCKED` clause of the `SELECT FOR UPDATE` statement. For information about these clauses, see Oracle Database SQL Language Reference.

See Also:

- *Oracle Database PL/SQL Language Reference*
- *Oracle Database SQL Language Reference*

8.4.5 Examples of Concurrency Under Explicit Locking

Table 8-2 shows how Oracle Database maintains data concurrency, integrity, and consistency when the `LOCK TABLE` statement and the `SELECT` statement with the `FOR UPDATE` clause are used. For brevity, the message text for ORA-00054 ("resource busy and acquire with `NOWAIT` specified") is not included. User-entered text is **bold**.

Note:

In tables compressed with Hybrid Columnar Compression (HCC), DML statements lock compression units rather than rows.

Table 8-2 Examples of Concurrency Under Explicit Locking

Time Point	Transaction 1	Transaction 2

1	**`LOCK TABLE hr.departments`**
	`IN ROW SHARE MODE;`
	
	`Statement processed.`	

2		**`DROP TABLE hr.departments;`**
		
		`DROP TABLE hr.departments`
		`*`
		`ORA-00054`
		
		(Exclusive DDL lock not possible because Transaction 1 has table locked.)

3		**`LOCK TABLE hr.departments`**
		`IN EXCLUSIVE MODE`
		`NOWAIT;`
		
		`ORA-00054`

4		**`SELECT location_id`**
		`FROM hr.departments`
		`WHERE department_id = 20`
		`FOR UPDATE OF location_id;`
		
		`LOCATION_ID`
		`-----------`
		`DALLAS`
		
		`1 row selected.`

5	**`UPDATE hr.departments`**
	`SET location_id = 'NEW YORK'`
	`WHERE department_id = 20;`
	
	(Waits because Transaction 2 locked same rows.)	

6		**`ROLLBACK;`** (Releases row locks.)

7	`1 row processed.`
	
	`ROLLBACK;`	

8	**`LOCK TABLE hr.departments`**
	`IN ROW EXCLUSIVE MODE;`
	
	`Statement processed.`	

Table 8-2 (Cont.) Examples of Concurrency Under Explicit Locking

Time Point	Transaction 1	Transaction 2

9		`LOCK TABLE hr.departments IN EXCLUSIVE MODE NOWAIT;`
		
		`ORA-00054`

10		`LOCK TABLE hr.departments IN SHARE ROW EXCLUSIVE MODE NOWAIT;`
		
		`ORA-00054`

11		`LOCK TABLE hr.departments IN SHARE ROW EXCLUSIVE MODE NOWAIT;`
		
		`ORA-00054`

12		`UPDATE hr.departments SET location_id = 'NEW YORK' WHERE department_id = 20;`
		
		`1 row processed.`

13		`ROLLBACK;`

14	`SELECT location_id FROM hr.departments WHERE department_id = 20 FOR UPDATE OF location_id;`
	
	`LOCATION_ID`
	`-----------`
	`DALLAS`
	
	`1 row selected.`	

15		`UPDATE hr.departments SET location_id = 'NEW YORK' WHERE department_id = 20;`
		
		`1 row processed.`
		
		(Waits because Transaction 1 locked same rows.)

16	`ROLLBACK;`	

Table 8-2 (Cont.) Examples of Concurrency Under Explicit Locking

Time Point	Transaction 1	Transaction 2

17		`1 row processed.`
		(Conflicting locks were released.)
		`ROLLBACK;`

18	**`LOCK TABLE hr.departments`**
	`IN ROW SHARE MODE`
	`Statement processed.`	

19		**`LOCK TABLE hr.departments`**
		`IN EXCLUSIVE MODE`
		`NOWAIT;`
		`ORA-00054`

20		**`LOCK TABLE hr.departments`**
		`IN SHARE ROW EXCLUSIVE MODE`
		`NOWAIT;`
		`ORA-00054`

21		**`LOCK TABLE hr.departments`**
		`IN SHARE MODE;`
		`Statement processed.`

22		**`SELECT location_id`**
		`FROM hr.departments`
		`WHERE department_id = 20;`
		`LOCATION_ID`
		`-----------`
		`DALLAS`
		`1 row selected.`

23		**`SELECT location_id`**
		`FROM hr.departments`
		`WHERE department_id = 20`
		`FOR UPDATE OF location_id;`
		`LOCATION_ID`
		`-----------`
		`DALLAS`
		`1 row selected.`

Table 8-2 (Cont.) Examples of Concurrency Under Explicit Locking

Time Point	Transaction 1	Transaction 2
24		`UPDATE hr.departments SET location_id = 'NEW YORK' WHERE department_id = 20;` (Waits because Transaction 1 has conflicting table lock.)
25	`ROLLBACK;`	

26		`1 row processed.`
		
		(Conflicting table lock released.)
		
		`ROLLBACK;`

27	`LOCK TABLE hr.departments IN SHARE ROW EXCLUSIVE MODE;`
	
	`Statement processed.`	

28		`LOCK TABLE hr.departments IN EXCLUSIVE MODE NOWAIT;`
		
		`ORA-00054`

29		`LOCK TABLE hr.departments IN SHARE ROW EXCLUSIVE MODE NOWAIT;`
		
		`ORA-00054`

30		`LOCK TABLE hr.departments IN SHARE MODE NOWAIT;`
		
		`ORA-00054`

31		`LOCK TABLE hr.departments IN ROW EXCLUSIVE MODE NOWAIT;`
		
		`ORA-00054`

32		`LOCK TABLE hr.departments IN SHARE MODE NOWAIT;`
		
		`ORA-00054`

Table 8-2 (Cont.) Examples of Concurrency Under Explicit Locking

Time Point	Transaction 1	Transaction 2

33		**`SELECT location_id`**
		`FROM hr.departments`
		`WHERE department_id = 20;`
		
		`LOCATION_ID`
		`-----------`
		`DALLAS`
		
		`1 row selected.`

34		**`SELECT location_id`**
		`FROM hr.departments`
		`WHERE department_id = 20`
		`FOR UPDATE OF location_id;`
		
		`LOCATION_ID`
		`-----------`
		`DALLAS`
		
		`1 row selected.`

35		**`UPDATE hr.departments`**
		`SET location_id = 'NEW YORK'`
		`WHERE department_id = 20;`
		
		(Waits because Transaction 1 has conflicting table lock.)

36	**`UPDATE hr.departments`**
	`SET location_id = 'NEW YORK'`
	`WHERE department_id = 20;`
	
	(Waits because Transaction 2 locked same rows.)
		(Deadlock.)

37	`Cancel operation.`
	
	`ROLLBACK;`	

38		`1 row processed.`

39	**`LOCK TABLE hr.departments`**
	`IN EXCLUSIVE MODE;`	

40		**`LOCK TABLE hr.departments`**
		`IN EXCLUSIVE MODE;`
		
		`ORA-00054`

Table 8-2 (Cont.) Examples of Concurrency Under Explicit Locking

Time Point	Transaction 1	Transaction 2

41		`LOCK TABLE hr.departments IN ROW EXCLUSIVE MODE NOWAIT;`
		
		`ORA-00054`

42		`LOCK TABLE hr.departments IN SHARE MODE;`
		
		`ORA-00054`

43		`LOCK TABLE hr.departments IN ROW EXCLUSIVE MODE NOWAIT;`
		
		`ORA-00054`

44		`LOCK TABLE hr.departments IN ROW SHARE MODE NOWAIT;`
		
		`ORA-00054`

45		`SELECT location_id FROM hr.departments WHERE department_id = 20;`
		
		`LOCATION_ID`
		`-----------`
		`DALLAS`
		
		`1 row selected.`

46		`SELECT location_id FROM hr.departments WHERE department_id = 20 FOR UPDATE OF location_id;` (Waits because Transaction 1 has conflicting table lock.)

47	`UPDATE hr.departments SET department_id = 30 WHERE department_id = 20;`
	
	`1 row processed.`	

48	`COMMIT;`	

Table 8-2 (Cont.) Examples of Concurrency Under Explicit Locking

Time Point	Transaction 1	Transaction 2
49		`0 rows selected.` (Transaction 1 released conflicting lock.)
50	**`SET TRANSACTION READ ONLY;`**	

51	**`SELECT location_id`**
	`FROM hr.departments`
	`WHERE department_id = 10;`
	
	`LOCATION_ID`
	`-----------`
	`BOSTON`	

52		**`UPDATE hr.departments`**
		`SET location_id = 'NEW YORK'`
		`WHERE department_id = 10;`
		
		`1 row processed.`

53	**`SELECT location_id`**
	`FROM hr.departments`
	`WHERE department_id = 10;`
	
	`LOCATION_ID`
	`-----------`
	`BOSTON`
	
	(Transaction 1 does not see uncommitted data.)	

54		**`COMMIT;`**

55	**`SELECT location_id`**
	`FROM hr.departments`
	`WHERE department_id = 10;`
	
	`LOCATION_ID`
	`-----------`
	`BOSTON`
	
	(Same result even after Transaction 2 commits.)	

56	**`COMMIT;`**	

Table 8-2 (Cont.) Examples of Concurrency Under Explicit Locking

Time Point	Transaction 1	Transaction 2

57	`SELECT location_id FROM hr.departments WHERE department_id = 10;`
	
	`LOCATION_ID`
	`-----------`
	`NEW YORK`
	
	(Sees committed data.)	

See Also:

Oracle Database Concepts

8.5 Using Oracle Lock Management Services (User Locks)

Your applications can use Oracle Lock Management services (user locks) by invoking subprograms the `DBMS_LOCK` package. An application can request a lock of a specific mode, give it a unique name (recognizable in another subprogram in the same or another instance), change the lock mode, and release it. Because a reserved user lock is an Oracle Database lock, it has all the features of a database lock, such as deadlock detection. Ensure that any user locks used in distributed transactions are released upon `COMMIT`, otherwise an undetected deadlock can occur.

See Also:

Oracle Database PL/SQL Packages and Types Reference for detailed information about the `DBMS_LOCK` package

Topics:

- When to Use User Locks
- Viewing and Monitoring Locks

8.5.1 When to Use User Locks

User locks can help:

- Provide exclusive access to a device, such as a terminal
- Provide application-level enforcement of read locks
- Detect when a lock is released and clean up after the application
- Synchronize applications and enforce sequential processing

Example 8-2 shows how the Pro*COBOL precompiler uses locks to ensure that there are no conflicts when multiple people must access a single device.

Example 8-2   How the Pro*COBOL Precompiler Uses Locks

```
******************************************************************
* Print Check                                                    *
* Any cashier may issue a refund to a customer returning goods.  *
* Refunds under $50 are given in cash, more than $50 by check.   *
* This code prints the check. One printer is opened by all       *
* the cashiers to avoid the overhead of opening and closing it   *
* for every check, meaning that lines of output from multiple    *
* cashiers can become interleaved if you do not ensure exclusive *
* access to the printer. The DBMS_LOCK package is used to        *
* ensure exclusive access.                                       *
******************************************************************
CHECK-PRINT
*     Get the lock "handle" for the printer lock.
   MOVE "CHECKPRINT" TO LOCKNAME-ARR.
   MOVE 10 TO LOCKNAME-LEN.
   EXEC SQL EXECUTE
      BEGIN DBMS_LOCK.ALLOCATE_UNIQUE ( :LOCKNAME, :LOCKHANDLE );
      END; END-EXEC.
*    Lock the printer in exclusive mode (default mode).
   EXEC SQL EXECUTE
      BEGIN DBMS_LOCK.REQUEST ( :LOCKHANDLE );
      END; END-EXEC.
*    You now have exclusive use of the printer, print the check.
  ...
*    Unlock the printer so other people can use it
EXEC SQL EXECUTE
      BEGIN DBMS_LOCK.RELEASE ( :LOCKHANDLE );
      END; END-EXEC.
```

8.5.2 Viewing and Monitoring Locks

Table 8-3 describes the Oracle Database facilities that display locking information for ongoing transactions within an instance.

Table 8-3   Ways to Display Locking Information

Tool	Description
Performance Monitoring Data Dictionary Views	See *Oracle Database Administrator's Guide*.
`UTLLOCKT.SQL`	The `UTLLOCKT.SQL` script displays a simple character lock wait-for graph in tree structured fashion. Using any SQL tool (such as SQL*Plus) to run the script, it prints the sessions in the system that are waiting for locks and the corresponding blocking locks. The location of this script file is operating system dependent. (You must have run the `CATBLOCK.SQL` script before using `UTLLOCKT.SQL`.)

8.6 Using Serializable Transactions for Concurrency Control

By default, Oracle Database permits concurrently running transactions to modify, add, or delete rows in the same table, and in the same data block. When transaction A changes a table, the changes are invisible to concurrently running transactions until transaction A commits them. If transaction A tries to update or delete a row that transaction B has locked (by issuing a DML or

`SELECT FOR UPDATE` statement), then the DML statement that A issued waits until B either commits or rolls back the transaction. This concurrency model, which provides higher concurrency and thus better performance, is appropriate for most applications.

However, some rare applications require serializable transactions. **Serializable transactions** run concurrently in serialized mode. In **serialized mode**, concurrent transactions can make only the database changes that they could make if they were running serially (that is, one at a time). If a serialized transaction tries to change data that another transaction changed after the serialized transaction began, then error ORA-08177 occurs.

When a serializable transaction fails with ORA-08177, the application can take any of these actions:

- Commit the work executed to that point.
- Run additional, different, statements, perhaps after rolling back to a prior savepoint in the transaction.
- Roll back the transaction and then rerun it.

  The transaction gets a transaction snapshot and the operation is likely to succeed.

Tip:

To minimize the performance overhead of rolling back and re running transactions, put DML statements that might conflict with concurrent transactions near the beginning of the transaction.

Note:

Serializable transactions do not work with deferred segment creation or interval partitioning. Trying to insert data into an empty table with no segment created, or into a partition of an interval partitioned table that does not yet have a segment, causes an error.

Topics:

- Transaction Interaction and Isolation Level
- Setting Isolation Levels
- Serializable Transactions and Referential Integrity
- READ COMMITTED and SERIALIZABLE Isolation Levels

8.6.1 Transaction Interaction and Isolation Level

The ANSI/ISO SQL standard defines three kinds of transaction interaction:

Transaction Interaction	Definition
Dirty read	Transaction A reads uncommitted changes made by transaction B.
Unrepeatable read	Transaction A reads data, transaction B changes the data and commits the changes, and transaction A rereads the data and sees the changes.

Transaction Interaction	Definition
Phantom read	Transaction A runs a query, transaction B inserts new rows and commits the change, and transaction A repeats the query and sees the new rows.

The kinds of interactions that a transaction can have is determined by its isolation level. The ANSI/ISO SQL standard defines four transaction isolation levels. Table 8-4 shows what kind of interactions are possible at each isolation level.

Table 8-4 ANSI/ISO SQL Isolation Levels and Possible Transaction Interactions

Isolation Level	Dirty Read	Unrepeatable Read	Phantom Read
`READ UNCOMMITTED`	Possible	Possible	Possible
`READ COMMITTED`	Not possible	Possible	Possible
`REPEATABLE READ`	Not possible	Not possible	Possible
`SERIALIZABLE`	Not possible	Not possible	Not possible

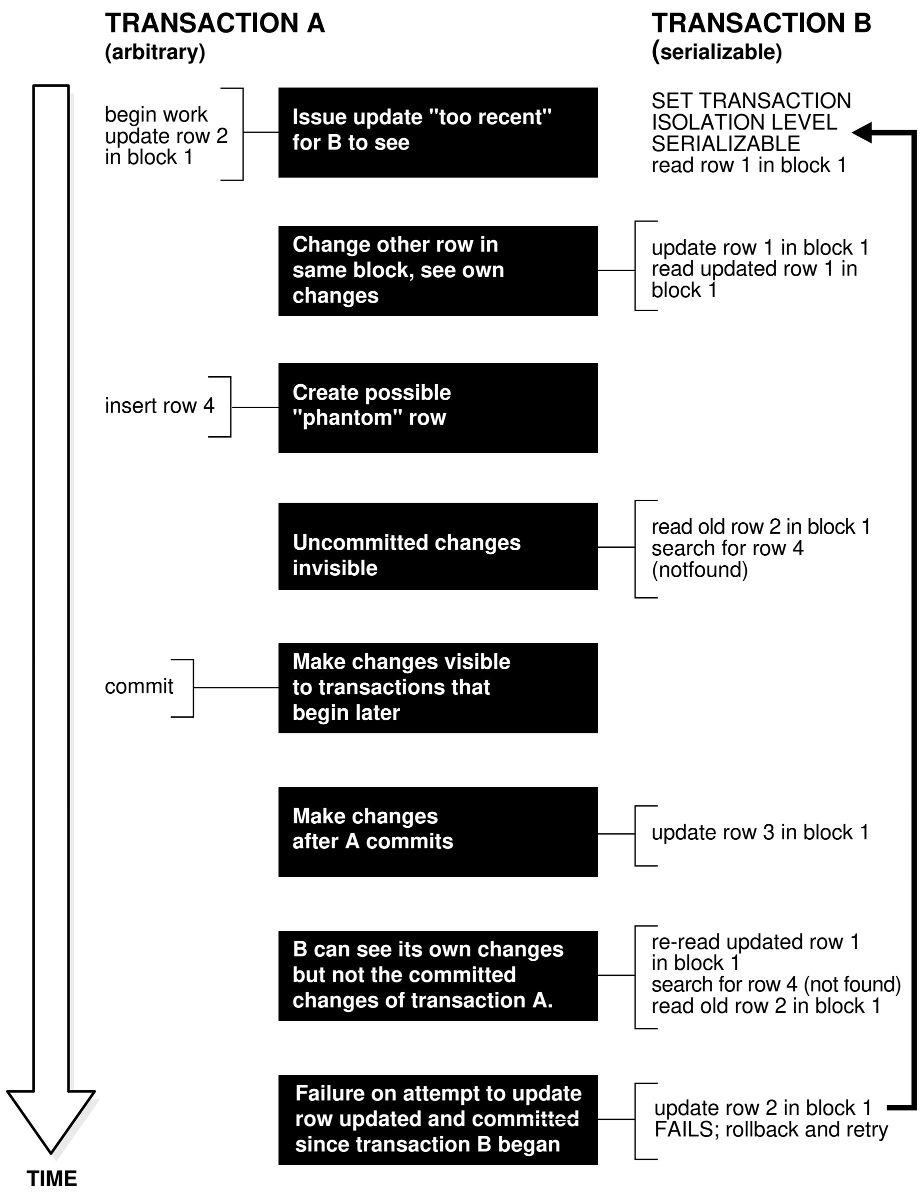
Table 8-5 shows which ANSI/ISO SQL transaction isolation levels Oracle Database provides.

Table 8-5 ANSI/ISO SQL Isolation Levels Provided by Oracle Database

Isolation Level	Provided by Oracle Database
`READ UNCOMMITTED`	No. Oracle Database never permits "dirty reads." Some other database products use this undesirable technique to improve throughput, but it is not required for high throughput with Oracle Database.
`READ COMMITTED`	Yes, by default. In fact, because an Oracle Database query sees only data that was committed at the beginning of the query (the snapshot time), Oracle Database offers more consistency than the ANSI/ISO SQL standard for `READ COMMITTED` isolation requires.
`REPEATABLE READ`	Yes, if you set the transaction isolation level to `SERIALIZABLE`.
`SERIALIZABLE`	Yes, if you set the transaction isolation level to `SERIALIZABLE`.

Figure 8-1 shows how an arbitrary transaction (that is, one that is either `SERIALIZABLE` or `READ COMMITTED`) interacts with a serializable transaction.

Figure 8-1 Interaction Between Serializable Transaction and Another Transaction


TRANSACTION A
(arbitrary)
TRANSACTION B
(serializable)
begin work
update row 2
in block 1
Issue update "too recent" for B to see
SET TRANSACTION
ISOLATION LEVEL
SERIALIZABLE
read row 1 in block 1
Change other row in same block, see own changes
update row 1 in block 1
read updated row 1 in block 1
insert row 4
Create possible "phantom" row
Uncommitted changes invisible
read old row 2 in block 1
search for row 4
(notfound)
commit
Make changes visible to transactions that begin later
Make changes after A commits
update row 3 in block 1
B can see its own changes but not the committed changes of transaction A.
re-read updated row 1
in block 1
search for row 4 (not found)
read old row 2 in block 1
Failure on attempt to update row updated and committed since transaction B began
update row 2 in block 1
FAILS; rollback and retry
TIME

8.6.2 Setting Isolation Levels

To set the transaction isolation level for every transaction in your session, use the `ALTER SESSION` statement.

To set the transaction isolation level for a specific transaction, use the `ISOLATION LEVEL` clause of the `SET TRANSACTION` statement. The `SET TRANSACTION` statement, must be the first statement in the transaction.

Note:

If you set the transaction isolation level to `SERIALIZABLE`, then you must use the `ALTER TABLE` statement to set the `INITRANS` parameter to at least 3. Use higher values for tables for which many transactions update the same blocks. For more information about `INITRANS`.

See Also:

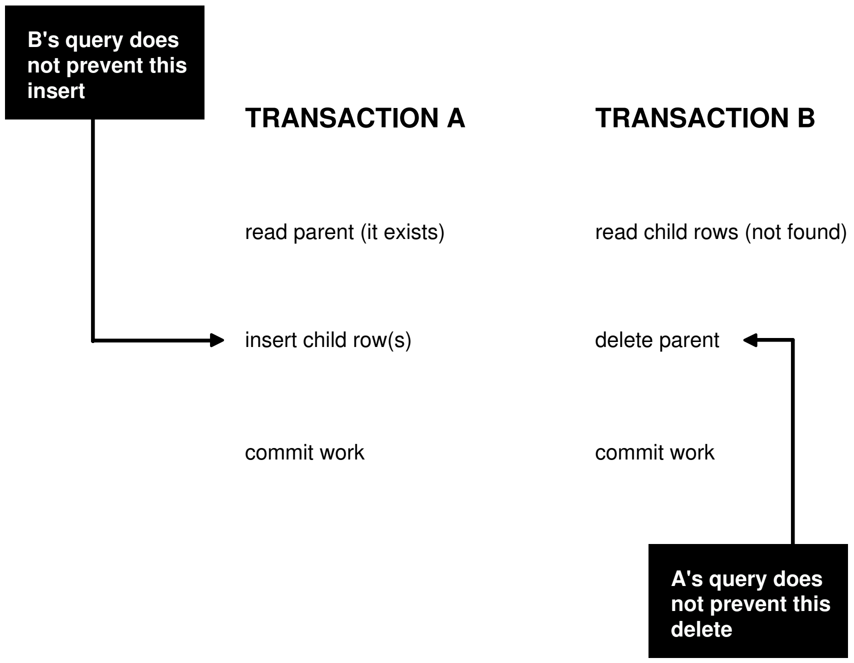
Oracle Database SQL Language Reference

8.6.3 Serializable Transactions and Referential Integrity

Because Oracle Database does not use read locks, even in `SERIALIZABLE` transactions, data read by one transaction can be overwritten by another. Therefore, transactions that perform database consistency checks at the application level must not assume that the data they read does not change during the transaction (even though such changes are invisible to the transaction). Code your application-level consistency checks carefully, even when using `SERIALIZABLE` transactions.

In Figure 8-2, transactions A and B (which are either `READ COMMITTED` or `SERIALIZABLE`) perform application-level checks to maintain the referential integrity of the parent/child relationship between two tables. Transaction A queries the parent table to check that it has a row with a specific primary key value before inserting corresponding child rows into the child table. Transaction B queries the child table to check that no child rows exist for a specific primary key value before deleting the corresponding parent row from the parent table. Both transactions assume (but do not ensure) that the data they read does not change before the transaction completes.

Figure 8-2 Referential Integrity Check


B's query does not prevent this insert
TRANSACTION A
TRANSACTION B
read parent (it exists)
read child rows (not found)
insert child row(s)
delete parent
commit work
commit work
A's query does not prevent this delete

The query by transaction A does not prevent transaction B from deleting the parent row, and the query by transaction B does not prevent transaction A from inserting child rows. Therefore, this can happen:

1. Transaction A queries the parent table and finds the specified parent row.
2. Transaction B queries the child table and finds no child rows for the specified parent row.
3. Having found the specified parent row, transaction A inserts the corresponding child rows into the child table.
4. Having found no child rows for the specified parent row, transaction B deletes the specified parent row from the parent table.

   Now the child rows that transaction A inserted in step 3 have no parent row.

The preceding result can occur even if both A and B are `SERIALIZABLE` transactions, because neither transaction prevents the other from changing the data that it reads to check consistency.

Ensuring that data queried by one transaction is not concurrently changed or deleted by another requires more transaction isolation than the ANSI/ISO SQL standard `SERIALIZABLE` isolation level provides. However, in Oracle Database:

- Transaction A can use a `SELECT FOR UPDATE` statement to query and lock the parent row, thereby preventing transaction B from deleting it.
- Transaction B can prevent transaction A from finding the parent row (thereby preventing A from inserting the child rows) by reversing the order of its processing steps. That is, transaction B can:
  1. Delete the parent row.
  2. Query the child table.
  3. If the deleted parent row has child rows in the child table, then roll back the deletion of the parent row.

Alternatively, you can enforce referential integrity with a trigger. Instead of having transaction A query the parent table, define on the child table a row-level `BEFORE INSERT` trigger that does this:

- Queries the parent table with a `SELECT FOR UPDATE` statement, thereby ensuring that if the parent row exists, then it remains in the database for the duration of the transaction that inserts the child rows.
- Rejects the insertion of the child rows if the parent row does not exist.

A trigger runs SQL statements in the context of the triggering statement (that is, the triggering and triggered statements see the database in the same state). Therefore, if a `READ COMMITTED` transaction runs the triggering statement, then the triggered statements see the database as it was when the triggering statement began to execute. If a `SERIALIZABLE` transaction runs the triggering statement, then the triggered statements see the database as it was at the beginning of the transaction. In either case, using `SELECT FOR UPDATE` in the trigger correctly enforces referential integrity.

See Also:

- *Oracle Database SQL Language Reference* for information about the `FOR UPDATE` clause of the `SELECT` statement
- *Oracle Database PL/SQL Language Reference* for more information about using triggers to maintain referential integrity between parent and child tables

8.6.4 READ COMMITTED and SERIALIZABLE Isolation Levels

Oracle Database provides two transaction isolation levels, `READ COMMITTED` and `SERIALIZABLE`. Both levels provide a high degree of consistency and concurrency, reduce contention, and are designed for real-world applications. This topic compares them and explains how to choose between them.

Topics:

- Transaction Set Consistency Differences
- Choosing Transaction Isolation Levels

8.6.4.1 Transaction Set Consistency Differences

An operation (query or transaction) is **transaction set consistent** if all of its read operations return data written by the same set of committed transactions. When an operation is not transaction set consistent, some of its read operations reflect the changes of one set of transactions and others reflect the changes of other sets of transactions; that is, the operation sees the database in a state that reflects no single set of committed transactions.

Topics:

- Oracle Database
- Other Database Systems

8.6.4.1.1 Oracle Database

Oracle Database transactions with `READ COMMITTED` isolation level are transaction set consistent on an individual-statement basis, because all rows that a query reads must be committed before the query begins.

Oracle Database transactions with `SERIALIZABLE` isolation level are transaction set consistent on an individual-transaction basis, because all statements in a `SERIALIZABLE` transaction run on an image of the database as it was at the beginning of the transaction.

8.6.4.1.2 Other Database Systems

In other database systems, a single query with `READ UNCOMMITTED` isolation level is not transaction set consistent, because it might see only a subset of the changes made by another transaction. For example, a join of a primary table with a detail table can see a primary record inserted by another transaction, but not the corresponding details inserted by that transaction (or the reverse). `READ COMMITTED` isolation level avoids this problem, providing more consistency than read-locking systems do.

In read-locking systems, at the cost of preventing concurrent updates, the `REPEATABLE READ` isolation level provides transaction set consistency at the statement level, but not at the transaction level. Due to the absence of phantom read protection, two queries in the same transaction can see data committed by different sets of transactions. In these systems, only the throughput-limiting and deadlock-susceptible `SERIALIZABLE` isolation level provides transaction set consistency at the transaction level.

8.6.4.2 Choosing Transaction Isolation Levels

The choice of transaction isolation level depends on performance and consistency needs and application coding requirements. There is a trade-off between concurrency (transaction throughput) and consistency. Consider the application and workload when choosing isolation levels for its transactions. Different transactions can have different isolation levels.

For environments with many concurrent users rapidly submitting transactions, consider expected transaction arrival rate, response time demands, and required degree of consistency.

`READ COMMITTED` isolation can provide considerably more concurrency with a somewhat increased risk of inconsistent results (from unrepeatable and phantom reads) for some transactions.

`SERIALIZABLE` isolation provides somewhat more consistency (by protecting against phantoms and unrepeatable reads), which might be important where a read/write transaction runs a query more than once. However, `SERIALIZABLE` isolation requires applications to check for the "cannot serialize access" error, and this checking can significantly reduce throughput in an environment with many concurrent transactions accessing the same data for update.

As explained in Serializable Transactions and Referential Integrity reads do not block writes in either `READ COMMITTED` or `SERIALIZABLE` transactions.

Table 8-6 summarizes the similarities and differences between `READ COMMITTED` and `SERIALIZABLE` transactions.

Table 8-6 Comparison of READ COMMITTED and SERIALIZABLE Transactions

Operation	READ COMMITTED	SERIALIZABLE
Dirty write	Not Possible	Not Possible
Dirty read	Not Possible	Not Possible
Unrepeatable read	Possible	Not Possible
Phantom read	Possible	Not Possible
Compliant with ANSI/ISO SQL 92	Yes	Yes
Read snapshot time	Statement	Transaction
Transaction set consistency	Statement level	Transaction level
Row-level locking	Yes	Yes
Readers block writers	No	No
Writers block readers	No	No
Different-row writers block writers	No	No
Same-row writers block writers	Yes	Yes
Waits for blocking transaction	Yes	Yes
Subject to "cannot serialize access" error	No	Yes

Table 8-6 (Cont.) Comparison of READ COMMITTED and SERIALIZABLE Transactions

Operation	READ COMMITTED	SERIALIZABLE
Error after blocking transaction terminates	No	No
Error after blocking transaction commits	No	Yes

See Also:

Serializable Transactions and Referential Integrity

8.7 Nonblocking and Blocking DDL Statements

The distinction between nonblocking and blocking DDL statements matters only for DDL statements that change either tables or indexes (which depend on tables).

When a session issues a DDL statement that affects object X, the session waits until every concurrent DML statement that references X is either committed or rolled back.

While the session waits, concurrent sessions might issue new DML statements. If the DDL statement is nonblocking, then the new DML statements execute immediately. If the DDL statement is blocking, then the new DML statements execute after the DDL statement completes, either successfully or with an error.

The `DDL_LOCK_TIMEOUT` parameter affects blocking DDL statements (but not nonblocking DDL statements). Therefore, a blocking DDL statement can complete with error `ORA-00054` (resource busy and acquire with `NOWAIT` specified or timeout expired).

A DDL statement that applies to a partition of a table is blocking for that partition but nonblocking for other partitions of the same table.

Caution:

Do not issue a nonblocking DDL statement in an autonomous transaction. See Autonomous Transactions for information about autonomous transactions

See Also:

- *Oracle Database Reference* for information about the `DDL_LOCK_TIMEOUT` parameter
- B Automatic and Manual Locking Mechanisms During SQL Operations for a list of nonblocking DDL statements
- ALTER DATABASE for information about enabling and disabling supplemental logging

8.8 Autonomous Transactions

Caution:

Do not issue a nonblocking DDL statement in an autonomous transaction.

An **autonomous transaction** (AT) is an independent transaction started by another transaction, the **main transaction** (MT). An autonomous transaction lets you suspend the main transaction, do SQL operations, commit or roll back those operations, and then resume the main transaction.

For example, in a stock purchase transaction, you might want to commit customer information regardless of whether the purchase succeeds. Or, you might want to log error messages to a debug table even if the transaction rolls back. Autonomous transactions let you do such tasks.

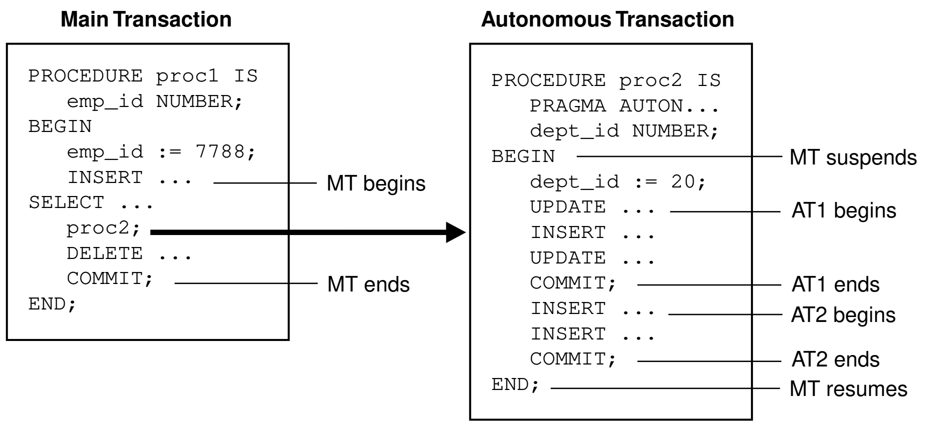
An autonomous transaction runs within an **autonomous scope**; that is, within the scope of an **autonomous routine**—a routine that you mark with the `AUTONOMOUS_TRANSACTION` pragma. In this context, a **routine** is one of these:

- Schema-level (not nested) anonymous PL/SQL block
- Standalone, package, or nested subprogram
- Method of an ADT
- Noncompound trigger

An autonomous routine can commit multiple autonomous transactions.

Figure 8-3 shows how control flows from the main transaction (`proc1`) to an autonomous routine (`proc2`) and back again. The autonomous routine commits two transactions (AT1 and AT2) before control returns to the main transaction.

Figure 8-3 Transaction Control Flow



```
PROCEDURE proc1 IS
   emp_id NUMBER;
BEGIN
   emp_id := 7788;
   INSERT ...
SELECT ...
   proc2;
   DELETE ...
   COMMIT;
END;
```

```
PROCEDURE proc2 IS
   PRAGMA AUTON...
   dept_id NUMBER;
BEGIN
   dept_id := 20;
   UPDATE ...
   INSERT ...
   UPDATE ...
   COMMIT;
   INSERT ...
   INSERT ...
   COMMIT;
END;
```

When you enter the executable section of an autonomous transaction, the main transaction suspends. When you exit the transaction, the main transaction resumes. `COMMIT` and `ROLLBACK` end the active autonomous transaction but do not exit the autonomous transaction. As

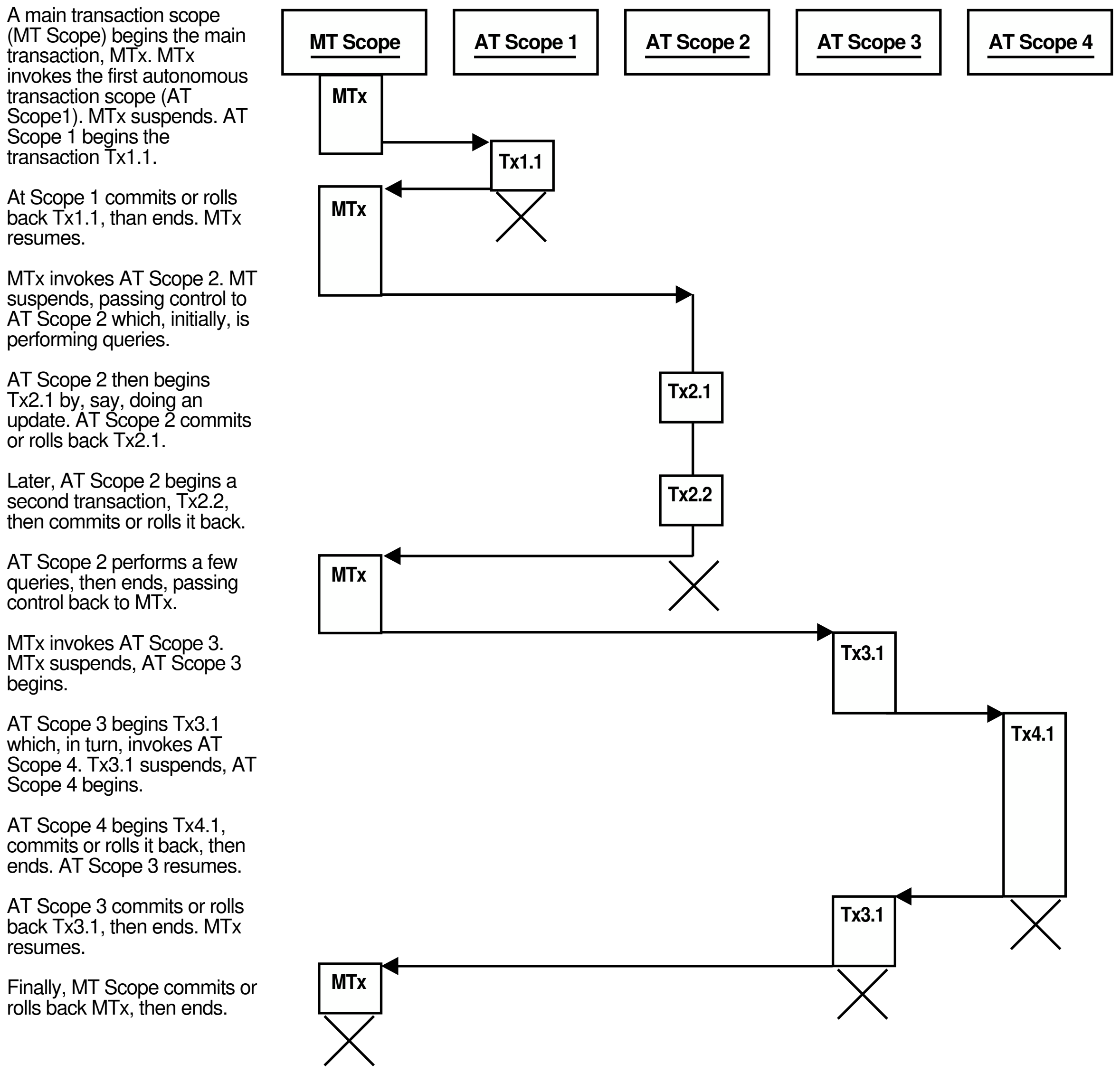
Figure 8-3 shows, when one transaction ends, the next SQL statement begins another transaction.

More characteristics of autonomous transactions:

- The changes an autonomous transaction effects do not depend on the state or the eventual disposition of the main transaction. For example:
  - An autonomous transaction does not see changes made by the main transaction.
  - When an autonomous transaction commits or rolls back, it does not affect the outcome of the main transaction.
- The changes an autonomous transaction effects are visible to other transactions as soon as that autonomous transaction commits. Therefore, users can access the updated information without having to wait for the main transaction to commit.
- Autonomous transactions can start other autonomous transactions.

Figure 8-4 shows some possible sequences that autonomous transactions can follow.

Figure 8-4   Possible Sequences of Autonomous Transactions



A main transaction scope (MT Scope) begins the main transaction, MTx. MTx invokes the first autonomous transaction scope (AT Scope1). MTx suspends. AT Scope 1 begins the transaction Tx1.1.

At Scope 1 commits or rolls back Tx1.1, than ends. MTx resumes.

MTx invokes AT Scope 2. MT suspends, passing control to AT Scope 2 which, initially, is performing queries.

AT Scope 2 then begins Tx2.1 by, say, doing an update. AT Scope 2 commits or rolls back Tx2.1.

Later, AT Scope 2 begins a second transaction, Tx2.2, then commits or rolls it back.

AT Scope 2 performs a few queries, then ends, passing control back to MTx.

MTx invokes AT Scope 3. MTx suspends, AT Scope 3 begins.

AT Scope 3 begins Tx3.1 which, in turn, invokes AT Scope 4. Tx3.1 suspends, AT Scope 4 begins.

AT Scope 4 begins Tx4.1, commits or rolls it back, then ends. AT Scope 3 resumes.

AT Scope 3 commits or rolls back Tx3.1, then ends. MTx resumes.

Finally, MT Scope commits or rolls back MTx, then ends.

Topics:

- Examples of Autonomous Transactions
- Declaring Autonomous Routines

See Also:

- *Oracle Database PL/SQL Language Reference* for detailed information about autonomous transactions
- Nonblocking and Blocking DDL Statements for information about nonblocking DDL statements

8.8.1 Examples of Autonomous Transactions

This section shows examples of autonomous transactions.

Topics:

- Ordering a Product
- Withdrawing Money from a Bank Account

As these examples show, there are four possible outcomes when you use autonomous and main transactions (see Table 8-7). There is no dependency between the outcome of an autonomous transaction and that of a main transaction.

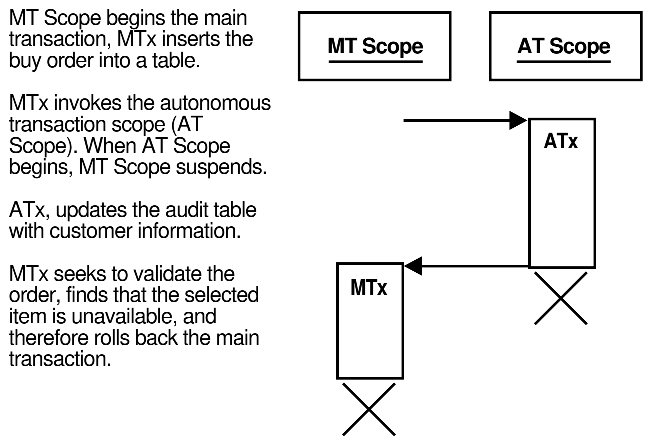
Table 8-7 Possible Transaction Outcomes

Autonomous Transaction	Main Transaction
Commits	Commits
Commits	Rolls back
Rolls back	Commits
Rolls back	Rolls back

8.8.1.1 Ordering a Product

Figure 8-5 shows an example of a customer ordering a product. The customer information (such as name, address, phone) is committed to a customer information table—even though the sale does not go through.

Figure 8-5 Example: A Buy Order


MT Scope begins the main transaction, MTx inserts the buy order into a table.
MTx invokes the autonomous transaction scope (AT Scope). When AT Scope begins, MT Scope suspends.
ATx, updates the audit table with customer information.
MTx seeks to validate the order, finds that the selected item is unavailable, and therefore rolls back the main transaction.
MT Scope
AT Scope
ATx
MTx

8.8.1.2 Withdrawing Money from a Bank Account

In this example, a customer tries to withdraw money from a bank account. In the process, a main transaction invokes one of two autonomous transaction scopes (AT Scope 1 or AT Scope 2).

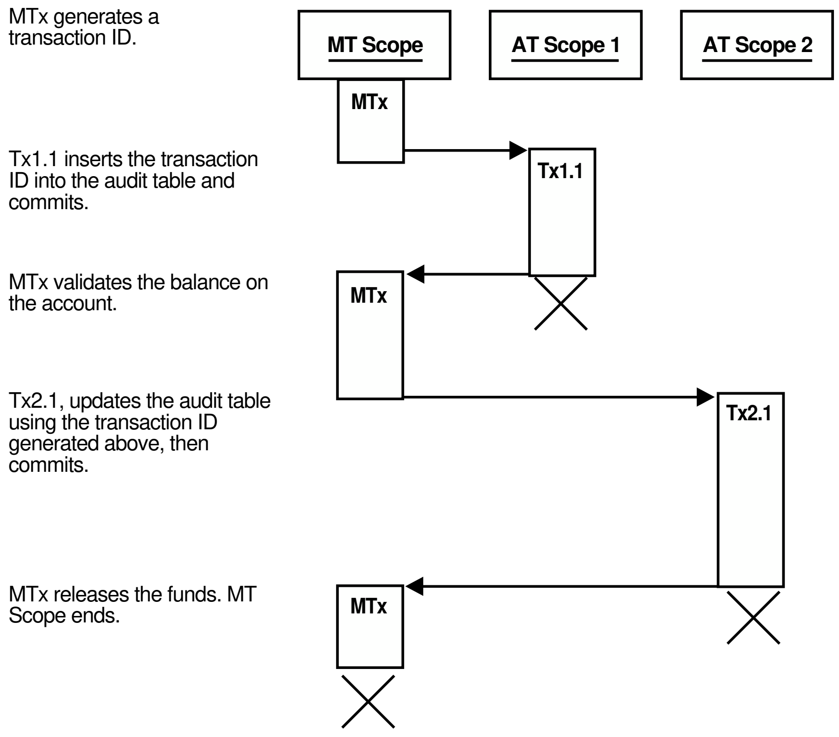
The possible scenarios for this transaction are:

- Scenario 1: Sufficient Funds
- Scenario 2: Insufficient Funds with Overdraft Protection
- Scenario 3: Insufficient Funds Without Overdraft Protection

8.8.1.2.1 Scenario 1: Sufficient Funds

There are sufficient funds to cover the withdrawal, so the bank releases the funds (see Figure 8-6).

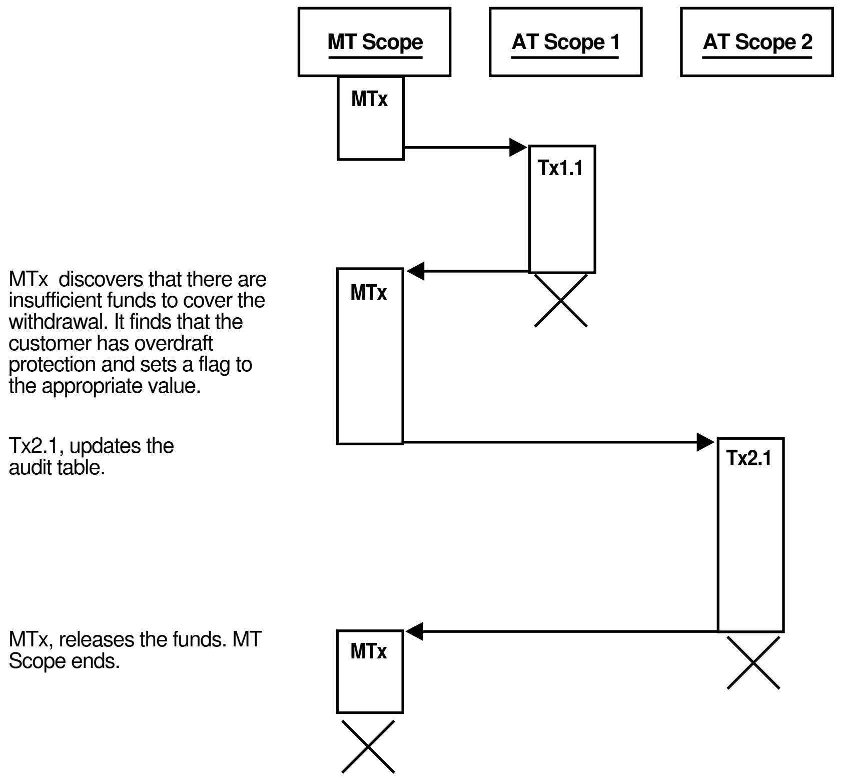
Figure 8-6 Bank Withdrawal—Sufficient Funds


MTx generates a transaction ID.
MT Scope
AT Scope 1
AT Scope 2
MTx
Tx1.1 inserts the transaction ID into the audit table and commits.
Tx1.1
MTx validates the balance on the account.
MTx
Tx2.1, updates the audit table using the transaction ID generated above, then commits.
Tx2.1
MTx releases the funds. MT Scope ends.
MTx

8.8.1.2.2 Scenario 2: Insufficient Funds with Overdraft Protection

There are insufficient funds to cover the withdrawal, but the customer has overdraft protection, so the bank releases the funds (see Figure 8-7).

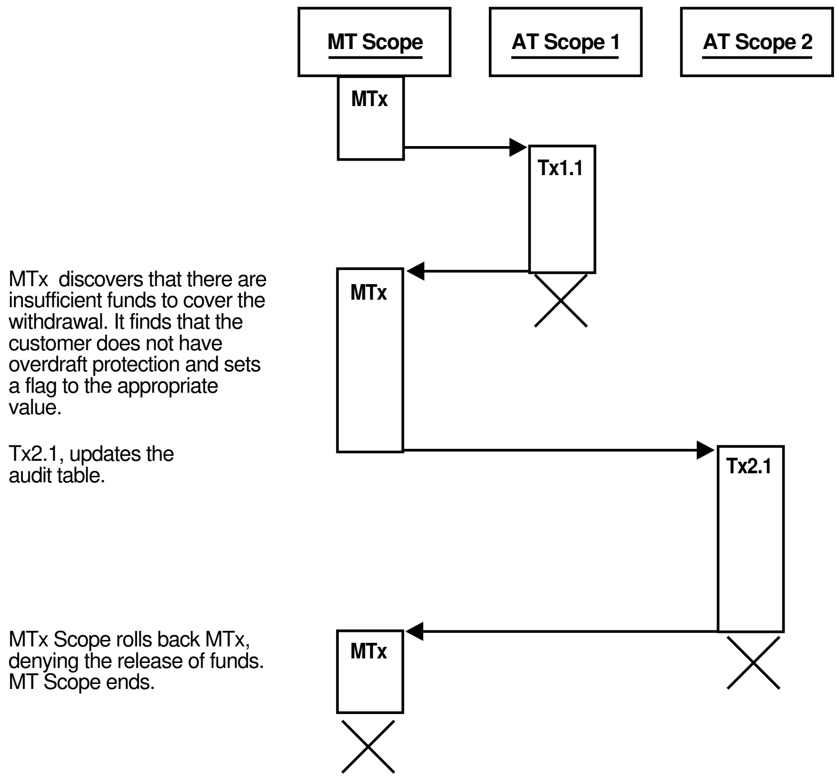
Figure 8-7   Bank Withdrawal—Insufficient Funds with Overdraft Protection


MT Scope
AT Scope 1
AT Scope 2
MTx
Tx1.1
MTx discovers that there are insufficient funds to cover the withdrawal. It finds that the customer has overdraft protection and sets a flag to the appropriate value.
MTx
Tx2.1, updates the audit table.
Tx2.1
MTx, releases the funds. MT Scope ends.
MTx

8.8.1.2.3 Scenario 3: Insufficient Funds Without Overdraft Protection

There are insufficient funds to cover the withdrawal and the customer does not have overdraft protection, so the bank withholds the requested funds (see Figure 8-8).

Figure 8-8 Bank Withdrawal—Insufficient Funds Without Overdraft Protection


MT Scope
AT Scope 1
AT Scope 2
MTx
Tx1.1
MTx
MTx discovers that there are insufficient funds to cover the withdrawal. It finds that the customer does not have overdraft protection and sets a flag to the appropriate value.
Tx2.1, updates the audit table.
Tx2.1
MTx Scope rolls back MTx, denying the release of funds. MT Scope ends.
MTx

8.8.2 Declaring Autonomous Routines

To declare an autonomous routine, use `PRAGMA AUTONOMOUS_TRANSACTION`, which instructs the PL/SQL compiler to mark the routine as autonomous.

See Also:

Oracle Database PL/SQL Language Reference for more information about `PRAGMA AUTONOMOUS_TRANSACTION`

In Example 8-3, the function `balance` is autonomous.

Example 8-3 Marking a Package Subprogram as Autonomous

```
-- Create table for package to use:

DROP TABLE accounts;
CREATE TABLE accounts (account INTEGER, balance REAL);

-- Create package:

CREATE OR REPLACE PACKAGE banking AS
  FUNCTION balance (acct_id INTEGER) RETURN REAL;
  -- Additional functions and packages
END banking;
/
```

```
CREATE OR REPLACE PACKAGE BODY banking AS
  FUNCTION balance (acct_id INTEGER) RETURN REAL IS
    PRAGMA AUTONOMOUS_TRANSACTION;
    my_bal  REAL;
  BEGIN
    SELECT balance INTO my_bal FROM accounts WHERE account=acct_id;
    RETURN my_bal;
  END;
  -- Additional functions and packages
END banking;
/
```

8.9 Resuming Execution After Storage Allocation Errors

When a long-running transaction is interrupted by a storage allocation error, the application can suspend the statement that encountered the problem, correct the problem, and then resume executing the statement. This capability, called **resumable storage allocation**, avoids time-consuming rollbacks. It also makes it unnecessary to split the operation into smaller pieces and write code to track its progress.

See Also:

Oracle Database Administrator's Guide for more information about resumable storage allocation

Topics:

- What Operations Have Resumable Storage Allocation?
- Handling Suspended Storage Allocation

8.9.1 What Operations Have Resumable Storage Allocation?

Queries, DML statements, and some DDL statements have resumable storage allocation after these kinds of errors:

- Out-of-space errors, such as ORA-01653.
- Space-limit errors, such as ORA-01628.
- Space-quota errors, such as ORA-01536.

Resumable storage allocation is possible whether the operation is performed directly by a SQL statement or within SQL*Loader, a stored subprogram, an anonymous PL/SQL block, or an OCI call such as `OCIStmtExecute`.

In dictionary-managed tablespaces, you cannot resume an index- or table-creating operation that encounters the limit for rollback segments or the maximum number of extents. You must use locally managed tablespaces and automatic undo management in combination with resumable storage allocation.

8.9.2 Handling Suspended Storage Allocation

When a statement in an application is suspended because of a storage allocation error, the application does not receive an error code. Therefore, either the application must use an `AFTER SUSPEND` trigger or the DBA must periodically check for suspended statements.

After the problem is corrected (usually by the DBA), the suspended statement automatically resumes execution. If the timeout period expires before the problem is corrected, then the statement raises a `SERVERERROR` exception.

Topics:

- Using an AFTER SUSPEND Trigger in the Application
- Checking for Suspended Statements

8.9.2.1 Using an AFTER SUSPEND Trigger in the Application

In the application, an `AFTER SUSPEND` trigger can get information about the problem by invoking subprograms in the `DBMS_RESUMABLE` package. Then the trigger can send the information to an operator, using email (for example).

To reduce the chance of out-of-space errors within the trigger itself, declare the trigger as an autonomous transaction. As an autonomous transaction, the trigger uses a rollback segment in the `SYSTEM` tablespace. If the trigger encounters a deadlock condition because of locks held by the suspended statement, then the trigger terminates and the application receives the original error code, as if the statement were never suspended. If the trigger encounters an out-of-space condition, then both the trigger and the suspended statement are rolled back. To prevent rollback, use an exception handler in the trigger to wait for the statement to resume.

The trigger in Example 8-4 handles storage errors within the database. For some kinds of errors, the trigger terminates the statement and alerts the DBA, using e-mail. For other errors, which might be temporary, the trigger specifies that the statement waits for eight hours before resuming, expecting the storage problem to be fixed by then. To run this example, you must connect to the database as `SYSDBA`.

See Also:

- *Oracle Database PL/SQL Packages and Types Reference*
- *Oracle Database PL/SQL Language Reference*

Example 8-4   AFTER SUSPEND Trigger Handles Suspended Storage Allocation

```
-- Create table used by trigger body

DROP TABLE rbs_error;
CREATE TABLE rbs_error (
  SQL_TEXT VARCHAR2(64),
  ERROR_MSG VARCHAR2(64),
  SUSPEND_TIME VARCHAR2(64)
);

-- Resumable Storage Allocation

CREATE OR REPLACE TRIGGER suspend_example
  AFTER SUSPEND
  ON DATABASE
DECLARE
  cur_sid           NUMBER;
  cur_inst          NUMBER;
  err_type          VARCHAR2(64);
  object_owner      VARCHAR2(64);
  object_type       VARCHAR2(64);
  table_space_name  VARCHAR2(64);
  object_name       VARCHAR2(64);
  sub_object_name   VARCHAR2(64);
  msg_body          VARCHAR2(64);
  ret_value         BOOLEAN;
  error_txt         VARCHAR2(64);
  mail_conn         UTL_SMTP.CONNECTION;
BEGIN
 SELECT DISTINCT(SID) INTO cur_sid FROM V$MYSTAT;
 cur_inst := USERENV('instance');
 ret_value := DBMS_RESUMABLE.SPACE_ERROR_INFO
              (err_type,
              object_owner,
              object_type,
              table_space_name,
              object_name,
              sub_object_name);
 IF object_type = 'ROLLBACK SEGMENT' THEN
   INSERT INTO rbs_error
     (SELECT SQL_TEXT, ERROR_MSG, SUSPEND_TIME
      FROM DBA_RESUMABLE
      WHERE SESSION_ID = cur_sid
      AND INSTANCE_ID = cur_inst);

    SELECT ERROR_MSG INTO error_txt
    FROM DBA_RESUMABLE
    WHERE SESSION_ID = cur_sid
    AND INSTANCE_ID = cur_inst;

    msg_body :=
     'Space error occurred: Space limit reached for rollback segment '
     || object_name || ' on ' || to_char(SYSDATE, 'Month dd, YYYY, HH:MIam')
     || '. Error message was: ' || error_txt;

    mail_conn := UTL_SMTP.OPEN_CONNECTION('localhost', 25);
    UTL_SMTP.HELO(mail_conn, 'localhost');
    UTL_SMTP.MAIL(mail_conn, 'sender@localhost');
    UTL_SMTP.RCPT(mail_conn, 'recipient@localhost');
    UTL_SMTP.DATA(mail_conn, msg_body);
    UTL_SMTP.QUIT(mail_conn);
    DBMS_RESUMABLE.ABORT(cur_sid);
  ELSE
    DBMS_RESUMABLE.SET_TIMEOUT(3600*8);
  END IF;
  COMMIT;
END;
/
```

8.9.2.2 Checking for Suspended Statements

If the application does not use an `AFTER SUSPEND` trigger, then the DBA must periodically check for suspended statements, using the static data dictionary view `DBA_RESUMABLE` .

The DBA can get additional information from the dynamic performance view `V$_SESSION_WAIT`.

See Also:

- `DBA_RESUMABLE`
- `V$_SESSION_WAIT`

8.10 Using `IF EXISTS` and `IF NOT EXISTS`

This section explains how to use `IF EXISTS` and `IF NOT EXISTS` with `CREATE`, `ALTER`, and `DROP` commands for different object types.

To ensure that your DDL statements are idempotent, the `CREATE`, `ALTER`, and `DROP` commands support the `IF EXISTS` and `IF NOT EXISTS` clauses. You can use these clauses to check if a given object exists or does not exist, and ensure that if the check fails, the command is ignored and does not generate an error. The `CREATE` DDL statement works with `IF NOT EXISTS` to suppress an error when an object already exists. Similarly, the `ALTER` and `DROP` DDL statements support the `IF EXISTS` clause to suppress an error when an object does not exist.

For example, you can control whether you need to know that a table exists before issuing the `DROP` command. If the existence of the table is not important, you can pass a statement similar to the following:

```
DROP TABLE IF EXISTS <table_name>...
```

If the table exists, the table is dropped. If the table does not exist, the statement is ignored and hence no error is raised. The same check mechanism exists for the creation of objects.

Assume a scenario where you do not have the `IF NOT EXISTS` support. Before issuing a query, you expect a table to exist but if it does not exist, a new one must be created. You would leverage PL/SQL or query the data dictionary to know if the table is present. If the table is not present, you would execute a dynamic SQL (`EXECUTE IMMEDIATE`) to create the table. With the `IF NOT EXISTS` support, you can issue a `CREATE TABLE IF NOT EXISTS <table_name>...` command to create a table if the table does not exist. If a table with this name exists, irrespective of the table's structure, the statement is ignored without generating an error.

Topics:

- Using `IF NOT EXISTS` with `CREATE` Command
- Using `IF EXISTS` with `ALTER` Command
- Using `IF EXISTS` with `DROP` Command
- Supported Object Types
- Limitations for `CREATE OR REPLACE` Statements
- SQL*Plus Output Messages for DDL Statements

8.10.1 Using `IF NOT EXISTS` with `CREATE` Command

The `IF NOT EXISTS` clause when used with the `CREATE` command, enables you to suppress an error if a given object does not exist. If the object already exists, the `CREATE` command with `IF NOT EXISTS` does not return an error. If the object does not exist, the `CREATE` command creates a new object.

The `CREATE` command supports the `IF NOT EXISTS` clause for many objects types.

> **See Also:**
>
> Supported Object Types for a complete list of the object types that support the `IF NOT EXISTS` clause.

Here is the syntax and an example of using `IF NOT EXISTS` with the `CREATE` command:

```
CREATE <object type> [IF NOT EXISTS] <rest of syntax>

-- create table if not exists
CREATE TABLE IF NOT EXISTS t1 (c1 number);
```

8.10.2 Using `IF EXISTS` with `ALTER` Command

The `IF EXISTS` clause when used with the `ALTER` command, enables you to suppress an error if a given object does not exist. If the object exists, the `ALTER` command with the `IF EXISTS` clause executes successfully.

The `ALTER` command supports the `IF EXISTS` clause for many objects types.

> **See Also:**
>
> Supported Object Types for a complete list of the object types that support the `IF EXISTS` clause.

Here is the syntax and an example of using `IF EXISTS` with the `ALTER` command:

```
ALTER <object type> [IF EXISTS] <rest of syntax>

-- alter table if exists
ALTER TABLE IF EXISTS t1;
```

8.10.3 Using `IF EXISTS` with `DROP` Command

The `IF EXISTS` clause when used with the `DROP` command, enables you to suppress an error if a given object does not exist. If the object exists, the `DROP` command with the `IF EXISTS` clause executes successfully.

The `DROP` command supports the `IF EXISTS` clause for many objects types.

> **See Also:**
>
> Supported Object Types for a complete list of the object types that support the `IF EXISTS` clause.

Here is the syntax and an example of using `IF EXISTS` with the `DROP` command:

```
DROP <object type> [IF EXISTS] <rest of syntax>

-- drop table if exists
DROP TABLE IF EXISTS t1;
```

8.10.4 Supported Object Types

These are the object types that support the `IF EXISTS` and `IF NOT EXISTS` clauses.

The following object types are supported for `CREATE ... IF NOT EXISTS`, `ALTER ... IF EXISTS`, and `DROP ... IF EXISTS` DDL statements.

Table 8-8 Object Types Supported for `CREATE`, `ALTER`, and `DROP` Commands

`CREATE` and `DROP` Commands	`ALTER` Command
ANALYTIC VIEW	ANALYTIC VIEW
ASSEMBLY	
ATTRIBUTE DIMENSION	ATTRIBUTE DIMENSION
CLUSTER	CLUSTER
DATABASE LINK	DATABASE LINK
DIRECTORY	
DOMAIN	DOMAIN
EDITION	
FUNCTION	FUNCTION
HIERARCHY	HIERARCHY
INDEX	
INDEXTYPE	INDEXTYPE
INMEMORY JOIN GROUP	INMEMORY JOIN GROUP
JAVA	JAVA
LIBRARY	LIBRARY
MATERIALIZED VIEW	MATERIALIZED VIEW
MATERIALIZED VIEW LOG	MATERIALIZED VIEW LOG
MATERIALIZED ZONEMAP	MATERIALIZED ZONEMAP
MLE ENV	MLE ENV
MLE MODULE	MLE MODULE
OPERATOR	OPERATOR
PACKAGE	PACKAGE
PACKAGE BODY	
PROCEDURE	PROCEDURE
PROPERTY GRAPH	PROPERTY GRAPH
SEQUENCE	SEQUENCE
SYNONYM	SYNONYM
TABLE	TABLE
TABLESPACE	TABLESPACE
TRIGGER	TRIGGER

Table 8-8 (Cont.) Object Types Supported for CREATE, ALTER, and DROP Commands

CREATE and DROP Commands	ALTER Command
TYPE	TYPE
TYPE BODY	
USER	USER
VIEW	VIEW

Limitations for IF [NOT] EXISTS

A subset of statements for the supported object types that are listed in Table 8-8 cannot be used with `IF [NOT] EXISTS`. These are DDL statements that may move data, add or drop partitions, revalidate a materialized view, or create or alter a private temporary table. In such cases, a custom error is raised, informing the user that the particular DDL statement cannot be used with `IF [NOT] EXISTS`.

The following are the statements that cannot be used with `IF [NOT] EXISTS`:

- `ALTER TABLE <table> ADD|DROP PARTITION ...`
- `ALTER TABLE <table> COALESCE PARTITION ...`
- `ALTER TABLE <table> MOVE ...`
- `ALTER MATERIALIZED VIEW <mat_view> MERGE PARTITIONS ...`
- `ALTER MATERIALIZED VIEW <mat_view> COMPILE ...`
- `CREATE TEMPORARY TABLE ...`
- `DROP TEMPORARY TABLE ...`

8.10.5 Limitations for CREATE OR REPLACE Statements

The `IF NOT EXISTS` clause is not allowed with the `CREATE OR REPLACE` syntax.

Here are some examples that illustrate how the `CREATE OR REPLACE` statement and the `CREATE` statement can or cannot be used with the `IF NOT EXISTS` clause:

```
-- not allowed, REPLACE cannot coexists with IF NOT EXISTS
CREATE OR REPLACE SYNONYM IF NOT EXISTS t1_syn FOR t1;

-- allowed
CREATE SYNONYM IF NOT EXISTS t1_syn FOR t1;

-- allowed
CREATE OR REPLACE SYNONYM t1_syn FOR t1;
```

8.10.6 SQL*Plus Output Messages for DDL Statements

To enable support for writing idempotent DDL scripts, the SQL*Plus output messages for the `CREATE`, `ALTER`, and `DROP` statements with `IF EXISTS` and `IF NOT EXISTS` commands, indicate a successful result even when an internal error related to an object's existence occurs. The suppression of error messages is intended by design, to allow users to write idempotent DDL statements. For instance, the following two statements, when executed one after another, generate the same 'Table created' output message, although the second statement does not create a new table.

```
CREATE TABLE T1 (COL NUMBER);
> Table created.

CREATE TABLE IF NOT EXISTS T1 (COL NUMBER);
> Table created.
```

There is no difference in the two output messages: the first, where the statement actually creates the table, and the second, where the table is not created because the table already exists. The second statement results in a no-op and suppresses the error. To know if an object already exists or not, you can run the DDL statements without the `IF [NOT] EXISTS` clause.