DATABASE MANAGEMENT SYSTEMS-ASSIGNMENT QUESTIONS

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1. ER Diagram Question:

Traffic Flow Management System (TFMS)

Scenario

You are tasked with designing an Entity-Relationship (ER) diagram for a Traffic Flow Management System (TFMS) used in a city to optimize traffic routes, manage intersections, and control traffic signals. The TFMS aims to enhance transportation efficiency by utilizing real-time data from sensors and historical traffic patterns.

ER diagram for the Traffic Flow Management System (TFMS):

Entities and Attributes

Roads

- RoadID (PK)

- RoadName

- Length (in meters)

- SpeedLimit (in km/h)

Intersections

- IntersectionID (PK)

- IntersectionName

- Latitude

- Longitude

Traffic Signals

- SignalID (PK)

- IntersectionID (FK referencing Intersections)

- SignalStatus (Green, Yellow, Red)

- Timer (countdown to next change)

Traffic Data

- TrafficDataID (PK)

- RoadID (FK referencing Roads)

- Timestamp

- Speed (average speed on the road)

- Congestion Level (degree of traffic congestion)

Relationships

A road can have multiple intersections (one-to-many): Roads -> Intersections

Cardinality: 1: N

Optionality: Mandatory (a road must have at least one intersection)

An intersection can have multiple roads (many-to-many): Intersections -> Roads

Cardinality: M: N

Optionality: Mandatory (an intersection must have at least one road)

An intersection can have one traffic signal (one-to-one): Intersections -> Traffic Signals

Cardinality: 1:1

Optionality: Optional (an intersection may not have a traffic signal)

A traffic signal is associated with one intersection (one-to-one): Traffic Signals -> Intersections

Cardinality: 1:1

Optionality: Mandatory (a traffic signal must be associated with an intersection)

A road can have multiple traffic data points (one-to-many): Roads -> Traffic Data

Cardinality: 1: N

Optionality: Mandatory (a road must have at least one traffic data point)

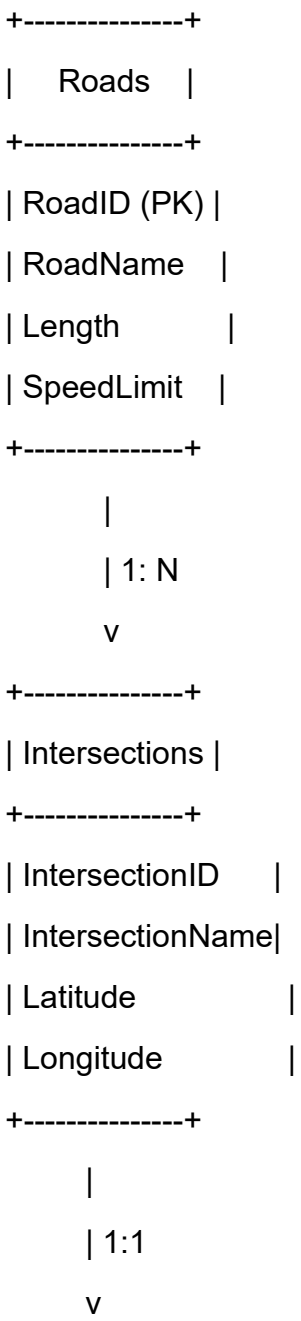
Normalization Considerations

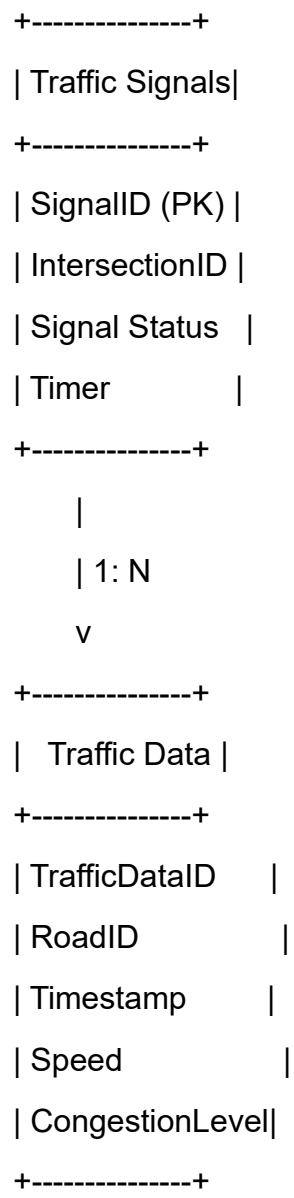
To ensure the ER diagram adheres to normalization principles, we can apply the following rules:

First Normal Form (1NF): Each table cell must contain a single value. This is already satisfied in the ER diagram**.**

Second Normal Form (2NF): Each non-key attribute in a table must depend on the entire primary key. This is satisfied since each attribute in each entity depends on the primary key of that entity.

Third Normal Form (3NF): If a table is in 2NF, and a non-key attribute depends on another non-key attribute, then it should be moved to a separate table. This is not applicable in this ER diagram since there are no transitive dependencies.





The relationships between the entities are represented by the lines connecting them:

- A road can have multiple intersections (one-to-many): Roads -> Intersections
- An intersection can have multiple roads (many-to-many): Intersections -> Roads
- An intersection can have one traffic signal (one-to-one): Intersections -> Traffic Signals
- A traffic signal is associated with one intersection (one-to-one): Traffic Signals -> Intersections
- A road can have multiple traffic data points (one-to-many): Roads -> Traffic Data

Here is a key to the notation used:

- (PK) indicates a primary key
- 1: N indicates a one-to-many relationship
- 1:1 indicates a one-to-one relationship
- M: N indicates a many-to-many relationship
- indicates a mandatory relationship (i.e., a relationship that must exist)
- indicates an optional relationship (i.e., a relationship that may or may not exist)

2.

Question 1: Top 3 Departments with Highest Average Salary

Task:

1. **Write a SQL query to find the top 3 departments with the highest average salary of employees. Ensure departments with no employees show an average salary of NULL.**

SQL Query

```
WITH department_salaries AS (
  SELECT
    d.DepartmentID,
    d.DepartmentName,
    AVG (e. Salary) AS AvgSalary
  FROM
    Departments d
  LEFT JOIN
    Employees e ON d. DepartmentID = e. DepartmentID
  GROUP BY
```

```
    d.DepartmentID, d. DepartmentName
)
SELECT
  DepartmentID,
  DepartmentName,
  AvgSalary
FROM
  department_salaries
ORDER BY
  AvgSalary DESC
LIMIT 3;
```

Explanation:

This SQL query finds the top 3 departments with the highest average salary of employees. It does this by:

- Joining the **Departments** table with the **Employees** table on the **DepartmentID** column
- Calculating the average salary for each department using the **AVG** function
- Including departments with no employees in the result set, with a **NULL** value for average salary
- Sorting the result set in descending order by average salary
- Returning only the top 3 departments with the highest average salary

Question 2: Retrieving Hierarchical Category Paths

Task:

1. **Write a SQL query using recursive Common Table Expressions (CTE) to retrieve all categories along with their full hierarchical path (e.g., Category > Subcategory > Sub-subcategory).**

SQL Query

```
WITH RECURSIVE category_hierarchy AS (
  -- Anchor query: Select top-level categories
  SELECT
    CategoryID,
    CategoryName,
    CAST (CategoryName AS VARCHAR(MAX)) AS HierarchicalPath,
    0 AS Level
  FROM
    Categories
  WHERE
    ParentCategoryID IS NULL
  UNION ALL
  -- Recursive query: Select child categories
  SELECT
    c.CategoryID,
    c.CategoryName,
    ch.HierarchicalPath + ' > ' + c.CategoryName,
    ch. Level + 1
  FROM
    Categories c
  INNER JOIN
    category_hierarchy ch ON c. ParentCategoryID = ch. CategoryID
)
SELECT
```

```
  CategoryID,
  CategoryName,
  HierarchicalPath
FROM
  category_hierarchy
ORDER BY
  HierarchicalPath;
```

Explanation of Recursive CTE

This SQL query uses a recursive Common Table Expression (CTE) to retrieve all categories along with their full hierarchical path. Here's what it does:

- It starts with the top-level categories (categories with no parent)
- Then, it recursively adds child categories to the result set, building the hierarchical path by concatenating the parent category's path with the child category's name
- The query continues to add child categories until it reaches the lowest level of the hierarchy
- Finally, it returns the category ID, category name, and the full hierarchical path for each category

Question 3: Total Distinct Customers by Month

Task:

1. **Design a SQL query to find the total number of distinct customers who made a purchase in each month of the current year. Ensure months with no customer activity show a count of 0.**

SQL Query

```
WITH Months AS (
  SELECT
    DATENAME (MONTH, DATEFROMPARTS (YEAR (GETDATE ()), m, 1)) AS MonthName
  FROM
```

```
    (VALUES (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12)) AS Months(m)
),
CustomerPurchases AS (
  SELECT
    DATENAME (MONTH, o. OrderDate) AS MonthName,
    COUNT (DISTINCT c. CustomerID) AS CustomerCount
  FROM
    Customers c
  INNER JOIN
    Orders o ON c. CustomerID = o. CustomerID
  WHERE
    YEAR (o. OrderDate) = YEAR (GETDATE ())
  GROUP BY
    DATENAME (MONTH, o. OrderDate)
)
SELECT
  m.MonthName,
  COALESCE (cp. CustomerCount, 0) AS CustomerCount
FROM
  Months m
  LEFT JOIN CustomerPurchases cp ON m. MonthName = cp. MonthName
ORDER BY
  m.MonthName;
```

Explanation of the Query

- **Months CTE**: The first CTE, **Months**, generates a list of all 12 months of the year using a derived table with **VALUES** clause. The **DATENAME** function is used to get the month name from the month number.
- **Customer Purchases CTE**: The second CTE, **Customer Purchases**, retrieves the number of distinct customers who made a purchase in each month of the current year. It joins the **Customers** and **Orders** tables, filters the orders by the current year, and groups the results by month.
- **LEFT JOIN**: The main query uses a **LEFT JOIN** to combine the **Months** CTE with the **Customer Purchases** CTE. This ensures that all months are included in the result set, even if there are no customer purchases in a particular month.
- **COALESCE**: The **COALESCE** function is used to replace **NULL** values in the **Customer Count** column with 0. This handles the case where there are no customer purchases in a month, ensuring that the result set shows a count of 0 for that month.
- **ORDER BY**: Finally, the result set is sorted by month name to ensure that the months are in the correct order.

Question 4: Finding Closest Locations

Task:

1. **Write a SQL query to find the closest 5 locations to a given point specified by latitude and longitude. Use spatial functions or advanced mathematical calculations for proximity**.

SQL Query

```
WITH ClosestLocations AS (
  SELECT
    l.LocationID,
    l.LocationName,
    l.Latitude,
    l.Longitude,
    (
```

```
      3959 * ACOS (
        COS(RADIANS(@lat)) * COS (RADIANS (l. Latitude)) *
        COS (RADIANS (l. Longitude) - RADIANS(@lon)) +
        SIN(RADIANS(@lat)) * SIN (RADIANS (l. Latitude))
      )
    ) AS Distance
  FROM
    Locations l
)
SELECT
  LocationID,
  LocationName,
  Latitude,
  Longitude,
  Distance
FROM
  ClosestLocations
ORDER BY
  Distance
LIMIT 5;
```

Explanation of the Mathematical Approach

The query uses the Haversine formula, a well-known algorithm for calculating the distance between two points on a sphere (such as the Earth) given their longitudes and latitudes. The formula is implemented using a combination of trigonometric functions and mathematical operations.

Here's a breakdown of the formula:

- **3959** is the average radius of the Earth in miles.
- **ACOS** calculates the inverse cosine of the angle between the two points.
- **COS(RADIANS(@lat))** and **COS (RADIANS (l. Latitude))** calculate the cosine of the latitude angles.
- **COS (RADIANS (l. Longitude) - RADIANS(@lon))** calculates the cosine of the longitude difference.
- **SIN(RADIANS(@lat))** and **SIN (RADIANS (l. Latitude))** calculate the sine of the latitude angles.
- The formula combines these values to calculate the distance between the two points.

Question 5: Optimizing Query for Orders Table

Task:

1. **Write a SQL query to retrieve orders placed in the last 7 days from a large Orders table, sorted by order date in descending order.**

SQL Query

```
SELECT
  o. OrderID,
  o. OrderDate,
  o. CustomerID,
  o. TotalAmount
FROM
  Orders o
WHERE
  o. OrderDate >= DATEADD (DAY, -7, CONVERT (DATE, GETDATE ()))
ORDER BY
  o. OrderDate DESC;
```

Discussion of Strategies Used to Optimize the Query

- **Indexing**: Creating an index on the **Order Date** column can significantly improve query performance. This is because the query filters on this column, and an index can help the database quickly locate the relevant rows.
- **Date arithmetic**: Instead of using a function like **DATEDIFF** to calculate the date range, I used the **DATEADD** function to subtract 7 days from the current date. This allows the database to use an index on the **Order Date** column.
- **Convert to date**: By converting the **GETDATE ()** function to a **DATE** data type, I ensured that the database can use an index on the **Order Date** column. This is because the **GETDATE ()** function returns a **DATETIME** value, which may not be compatible with the **DATE** data type of the **Order Date** column.
- **Avoid using functions in the WHERE clause**: By rewriting the query to use a date range instead of a function like **DATEDIFF**, I avoided the need for the database to evaluate the function for each row. This can improve performance, especially for large tables.
- **Optimized sorting**: By sorting the results in descending order by **Order Date**, I ensured that the database can use an index on this column to optimize the sorting operation.

3.

PL/SQL Questions

Question 1: Handling Division Operation

Task:

1. **Write a PL/SQL block to perform a division operation where the divisor is obtained from user input. Handle the ZERO_DIVIDE exception gracefully with an appropriate error message.**

PL/SQL Query

```
DECLARE
```

```
  dividend NUMBER: = 10;
  divisor NUMBER;
  result NUMBER;
BEGIN
  divisor: = &enter_divisor; -- obtain divisor from user input
  BEGIN
    result: = dividend / divisor;
    DBMS_OUTPUT.PUT_LINE ('Result: ' || result);
  EXCEPTION
  WHEN ZERO_DIVIDE THEN
    DBMS_OUTPUT.PUT_LINE ('Error: Division by zero');
  END;
END;
```

Explanation of error handling strategies implemented:

The code uses a nested BEGIN-END block to catch the specific exception obtained from a division operation. The divisor is obtained from user input, and the division operation is performed inside the inner BEGIN-END block. If a division by zero exception is raised, the EXCEPTION block immediately follows the division operation and catches the ZERO_DIVIDE exception. Inside the EXCEPTION block, an error message is displayed indicating that a division by zero has occurred. This approach ensures that the program does not terminate abruptly due to the exception, but instead handles it gracefully and provides a meaningful error message to the user.

Question 2: Updating Rows with FORALL

Task:

1. **Use the FORALL statement to update multiple rows in the Employees table based on arrays of employee IDs and salary increments.**

PL/SQL Query

```
DECLARE
  TYPE emp_id_array IS VARRAY (10) OF NUMBER;
  TYPE salary_inc_array IS VARRAY (10) OF NUMBER;

  emp_ids emp_id_array: = emp_id_array (101, 102, 103, 104, 105);
  salary_incs salary_inc_array: = salary_inc_array (1000, 2000, 3000, 4000, 5000);

BEGIN
  FORALL i IN 1.emp_ids. COUNT
    UPDATE Employees
    SET salary = salary + salary_incs(i)
    WHERE employee_id = emp_ids(i);
COMMIT;
END;
```

Description of how FORALL improves performance for bulk updates:

The FORALL statement is a bulk DML (Data Manipulation Language) statement that allows you to execute a single DML statement multiple times, with each iteration using a different set of values from an array. In this example, we use two arrays, emp_ids and salary_incs, to store the employee IDs and corresponding salary increments.

1. **Reduced number of SQL statements**: Instead of executing multiple individual UPDATE statements, one for each employee, the FORALL statement executes a single UPDATE statement that updates multiple rows in a single operation.

2. **Improved performance**: By reducing the number of SQL statements, the FORALL statement minimizes the overhead of parsing, binding, and executing individual statements.
3. **Enhanced concurrency**: FORALL statements can take advantage of Oracle's parallel processing capabilities, allowing multiple updates to be executed concurrently, further improving performance.
4. **Error handling**: If an error occurs during the execution of the FORALL statement, Oracle rolls back the entire operation, ensuring data consistency and integrity.

Question 3: Implementing Nested Table Procedure

Task:

1. **Implement a PL/SQL procedure that accepts a department ID as input, retrieves employees belonging to the department, stores them in a nested table type, and returns this collection as an output parameter.**

PL/SQL Query

```
CREATE OR REPLACE TYPE employee_type AS OBJECT (
  employee_id NUMBER,
  first_name VARCHAR2(20),
  last_name VARCHAR2(20)
);
CREATE OR REPLACE TYPE employee_collection AS TABLE OF employee_type;
CREATE OR REPLACE PROCEDURE get_department_employees(
  p_department_id IN NUMBER,
  p_employees OUT employee_collection
) AS
```

```
BEGIN
  SELECT employee_type (e. employee_id, e. first_name, e. last_name)
  BULK COLLECT INTO p_employees
  FROM Employees e
  WHERE e. department_id = p_department_id;
END get_department_employees;
```

Explanation of how nested tables are utilized and returned as output:

1. **Nested Table Type**: We define a nested table type **employee_collection** as a table of **employee_type** objects. This allows us to store a collection of employee records.
2. **Procedure Definition**: The **get_department_employees** procedure takes two parameters: **p_department_id** (input) and **p_employees** (output). The output parameter **p_employees** is of type **employee_collection**.
3. **BULK COLLECT INTO**: Inside the procedure, we use the **BULK COLLECT INTO** statement to retrieve the employees belonging to the specified department and store them in the **p_employees** collection. This statement allows us to fetch multiple rows into a single collection.
4. **Returning the Collection**: The **p_employees** collection is returned as an output parameter, which can be accessed by the calling program.

Question 4: Using Cursor Variables and Dynamic SQL

Task:

1. **Write a PL/SQL block demonstrating the use of cursor variables (REF CURSOR) and dynamic SQL. Declare a cursor variable for querying EmployeeID, FirstName, and LastName based on a specified salary threshold.**

PL/SQL Query

```
DECLARE
  -- Declare a REF CURSOR type
  TYPE ref_cursor IS REF CURSOR;
-- Declare a cursor variable
  v_cursor ref_cursor;
-- Declare variables to hold the dynamic SQL statement and its parameters
  v_sql_stmt VARCHAR2(200);
  v_salary_threshold NUMBER: = 50000;

  -- Declare variables to hold the query results
  v_employee_id NUMBER;
  v_first_name VARCHAR2(20);
  v_last_name VARCHAR2(20);
BEGIN
  -- Construct the dynamic SQL statement
  v_sql_stmt := 'SELECT employee_id, first_name, last_name FROM Employees
WHERE salary > :salary_threshold';

-- Open the cursor variable with the dynamic SQL statement
  OPEN v_cursor FOR v_sql_stmt USING v_salary_threshold;
-- Fetch the query results
  LOOP
    FETCH v_cursor INTO v_employee_id, v_first_name, v_last_name;
    EXIT WHEN v_cursor%NOTFOUND;
-- Process the query results
```

```
    DBMS_OUTPUT.PUT_LINE ('Employee ID: ' || v_employee_id || ', Name: ' ||
v_first_name || ' ' || v_last_name);

END LOOP;
-- Close the cursor variable
  CLOSE v_cursor;
END;
```

Explanation of how dynamic SQL is constructed and executed:

1. Declaring a REF CURSOR type: We declare a REF CURSOR type, which is a pointer to a cursor.
2. Declaring a cursor variable: We declare a cursor variable v_cursor of type REF CURSOR.
3. Constructing the dynamic SQL statement: We construct a dynamic SQL statement as a string, using a placeholder: salary_threshold for the salary threshold parameter.
4. Opening the cursor variable: We open the cursor variable with the dynamic SQL statement, passing the v_salary_threshold parameter as a bind variable.
5. Fetching the query results: We fetch the query results using a LOOP statement, which iterates over the rows returned by the cursor.
6. Processing the query results: We process the query results by printing the employee ID, first name, and last name to the console.
7. Closing the cursor variable: We close the cursor variable to release system resources.

Dynamic SQL is constructed by concatenating strings to form a SQL statement. In this example, we construct a SELECT statement with a WHERE clause that filters employees based on a salary threshold. The: salary_**threshold** placeholder is replaced with the actual value of **v_salary_threshold** when the cursor is opened.

Question 5: Designing Pipelined Function for Sales Data

Task:

1. **Design a pipelined PL/SQL function get_sales_data that retrieves sales data for a given month and year. The function should return a table of records containing OrderID, CustomerID, and OrderAmount for orders placed in the specified month and year.**

PL/SQL Query:

```
CREATE OR REPLACE PACKAGE sales_data_pkg AS
  TYPE sales_data_rec IS RECORD (
    order_id NUMBER,
    customer_id NUMBER,
    order_amount NUMBER
  );
TYPE sales_data_tbl IS TABLE OF sales_data_rec;
FUNCTION get_sales_data(p_month IN NUMBER, p_year IN NUMBER)
    RETURN sales_data_tbl PIPELINED;
END sales_data_pkg;
CREATE OR REPLACE PACKAGE BODY sales_data_pkg AS
  FUNCTION get_sales_data(p_month IN NUMBER, p_year IN NUMBER)
    RETURN sales_data_tbl PIPELINED AS
  BEGIN
    FOR cur_rec IN (
      SELECT order_id, customer_id, order_amount
```

```
      FROM orders
      WHERE EXTRACT (MONTH FROM order_date) = p_month
        AND EXTRACT (YEAR FROM order_date) = p_year
    ) LOOP
      PIPE ROW (sales_data_rec(cur_rec.order_id, cur_rec.customer_id,
cur_rec.order_amount));
    END LOOP;
    RETURN;
  END get_sales_data;
END sales_data_pkg;
```

Explanation of how pipelined table functions improve data retrieval efficiency:

1. Pipelined Functions: A pipelined function is a type of table function that returns a table of records in a pipelined manner, allowing the caller to process the data in a streaming fashion.
2. Improved Efficiency: Pipelined table functions improve data retrieval efficiency in several ways:
    - Reduced Memory Usage: By processing the data in a pipelined manner, the function only needs to store a small amount of data in memory at a time, reducing the memory footprint and improving performance.
    - Faster Data Retrieval: Pipelined functions can return data to the caller as soon as it is available, rather than waiting for the entire result set to be generated. This can significantly improve data retrieval times, especially for large datasets.
    - Improved Scalability: Pipelined functions can handle large datasets more efficiently, making them more scalable and suitable for big data applications.

3. How it Works: In the get_sales_data function, we use a cursor to iterate over the orders table, filtering the data based on the specified month and year. For each row, we use the PIPE ROW statement to return a single record to the caller, allowing the data to be processed in a streaming fashion.
4. Caller Perspective: From the caller's perspective, the pipelined function returns a table of records that can be processed using a cursor or a loop. The caller can process the data as it is returned, without having to wait for the entire result set to be generated.