CSA09: DATABASE MANAGEMENT SYSTEMS-ASSIGNMENT QUESTIONS

Question 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.

The city administration has decided to implement a TFMS to address growing traffic congestion issues. The system will integrate real-time data from traffic sensors, cameras, and historical traffic patterns to provide intelligent traffic management solutions. Key functionalities include:

1. **Road Network Management**:
    - **Roads**: The city has a network of roads, each identified by a unique RoadID. Roads have attributes such as RoadName, Length (in meters), and SpeedLimit (in km/h).
2. **Intersection Control**:
    - **Intersections**: These are key points where roads meet and are crucial for traffic management. Each intersection is uniquely identified by IntersectionID and has attributes like IntersectionName and geographic Coordinates (Latitude, Longitude).
3. **Traffic Signal Management**:
    - **Traffic Signals**: Installed at intersections to regulate traffic flow. Each signal is identified by SignalID and has attributes such as SignalStatus (Green, Yellow, Red) indicating current state and Timer (countdown to next change).
4. **Real-Time Data Integration**:
    - **Traffic Data**: Real-time data collected from sensors includes TrafficDataID, Timestamp, Speed (average speed on the road), and CongestionLevel (degree of traffic congestion).
5. **Functionality Requirements**:
    - **Route Optimization**: Algorithms will be implemented to suggest optimal routes based on current traffic conditions.
    - **Traffic Signal Control**: Adaptive control algorithms will adjust signal timings dynamically based on real-time traffic flow and congestion data.
    - **Historical Analysis**: The system will store historical traffic data for analysis and planning future improvements.

ER Diagram Design Requirements

1. **Entities and Attributes**:
    - Clearly define entities (Roads, Intersections, Traffic Signals, Traffic Data) and their attributes based on the scenario provided.

- Include primary keys (PK) and foreign keys (FK) where necessary to establish relationships between entities.

2. **Relationships**:
   - Illustrate relationships between entities (e.g., Roads connecting to Intersections, Intersections hosting Traffic Signals).
   - Specify cardinality (one-to-one, one-to-many, many-to-many) and optionality constraints (mandatory vs. optional relationships).
3. **Normalization Considerations**:
   - Discuss how you would ensure the ER diagram adheres to normalization principles (1NF, 2NF, 3NF) to minimize redundancy and improve data integrity.

Tasks

Task 1: Entity Identification and Attributes

Identify and list the entities relevant to the TFMS based on the scenario provided (e.g., Roads, Intersections, Traffic Signals, Traffic Data).

Define attributes for each entity, ensuring clarity and completeness.

1. **Roads**
- **Attributes:**
- **RoadID** (Primary Key, PK): Unique identifier for each road.
- **RoadName**: Name of the road.
- **Length**: Length of the road in meters.
- **SpeedLimit**: Speed limit in km/h.

2. **Intersections**
- **Attributes:**
- **IntersectionID** (PK): Unique identifier for each intersection.
- **IntersectionName**: Name or description of the intersection.
- **Latitude**: Geographic latitude coordinate.
- **Longitude**: Geographic longitude coordinate.

3. **Traffic Signals**
- **Attributes:**
- **SignalID** (PK): Unique identifier for each traffic signal.
- **SignalStatus**: Current status (Green, Yellow, Red).
- **Timer**: Countdown timer to the next signal change.
- **IntersectionID** (Foreign Key, FK): Identifier of the intersection where the signal is located.

4. **Traffic Data**
- **Attributes:**
- **TrafficDataID** (PK): Unique identifier for each traffic data record.
- **Timestamp**: Date and time of the data capture.

- **Speed**: Average speed on the road (in km/h).
- **CongestionLevel**: Degree of traffic congestion (e.g., Low, Medium, High).
- **RoadID** (FK): Identifier of the road where the data was collected.

Task 2: Relationship Modeling

Illustrate the relationships between entities in the ER diagram (e.g., Roads connecting to Intersections, Intersections hosting Traffic Signals).

Specify cardinality (one-to-one, one-to-many, many-to-many) and optionality constraints (mandatory vs. optional relationships).

1. **Roads and Intersections**
- **Relationship:** A road can intersect with multiple roads, and each intersection involves multiple roads.
- **Cardinality:** Many-to-Many (A road can be part of multiple intersections and an intersection can involve multiple roads).
- **Optionality:** Mandatory for intersections, as each intersection must be formed by roads.
2. **Intersections and Traffic Signals**
- **Relationship:** Each intersection can have multiple traffic signals.
- **Cardinality:** One-to-Many (One intersection can have many traffic signals, but each traffic signal is located at one intersection).
- **Optionality:** Optional for traffic signals, as not all intersections may have traffic signals.
3. **Roads and Traffic Data**
- **Relationship:** Traffic data is collected for specific roads.
- **Cardinality:** One-to-Many (One road can have many traffic data records, but each traffic data record pertains to one specific road).
- **Optionality:** Mandatory for traffic data, as each record must be linked to a road.

Task 3: ER Diagram Design

Draw the ER diagram for the TFMS, incorporating all identified entities, attributes, and relationships.

Label primary keys (PK) and foreign keys (FK) where applicable to establish relationships between entities.

1. **Entities and Their Attributes:**

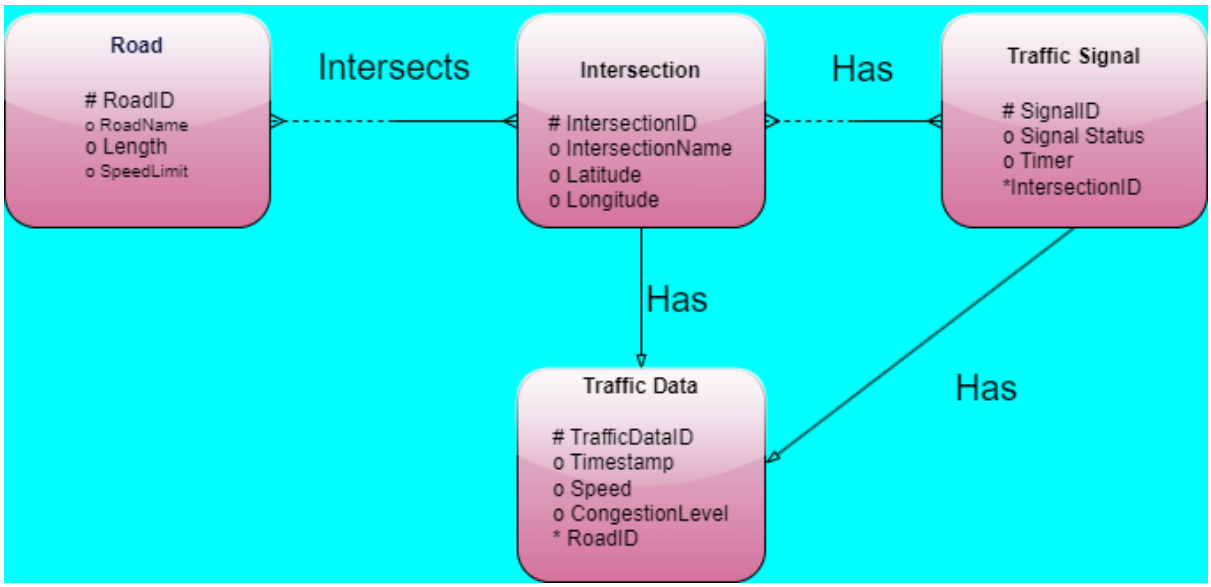
- Draw boxes for each entity: Roads, Intersections, Traffic Signals, and Traffic Data.
- List attributes inside the boxes, underlining primary keys and italicizing foreign keys.

2. **Relationships and Cardinality:**

- **Roads - Intersections:** Draw a diamond representing the "Intersects" relationship. Connect it with lines to both the Roads and Intersections entities. Use a many-to-many notation.
- **Intersections - Traffic Signals:** Draw a diamond representing the "Has" relationship. Connect it with a line from Intersections to Traffic Signals. Use a one-to-many notation.
- **Roads - Traffic Data:** Draw a diamond representing the "Monitored by" relationship. Connect it with a line from Roads to Traffic Data. Use a one-to-many notation.

3. **Primary and Foreign Keys:**

- Clearly label PKs and FKs in the entity boxes and on the connecting lines.



Task 4: Justification and Normalization

Justify your design choices, including considerations for scalability, real-time data processing, and efficient traffic management.

Discuss how you would ensure the ER diagram adheres to normalization principles (1NF, 2NF, 3NF) to minimize redundancy and improve data integrity.

1. Justification:

- **Scalability:** The ER diagram supports scalability by allowing for additional attributes and entities, such as adding more sensors or traffic data points as the city expands.

- **Real-Time Data Processing:** The inclusion of Traffic Data with timestamping allows real-time and historical data processing, facilitating route optimization and signal control.
- **Efficient Traffic Management:** By separating traffic data from roads and using foreign keys, the diagram ensures efficient query performance and data integrity for traffic management operations.

2. Normalization Considerations:

- **1NF (First Normal Form):** Ensure that each entity's attributes contain only atomic values, with no repeating groups.
- **2NF (Second Normal Form):** Ensure that all non-key attributes are fully functionally dependent on the primary key. For example, Traffic Data depends on RoadID, not just a part of it.
- **3NF (Third Normal Form):** Ensure that no transitive dependencies exist. Attributes like SignalStatus and Timer in Traffic Signals depend only on SignalID, not on other non-key attributes.

Deliverables

1. **ER Diagram:**

- Draw the ER diagram with all entities, attributes, relationships, primary keys, and foreign keys clearly labeled.

2. **Entity Definitions:**

- Provide definitions and attributes for Roads, Intersections, Traffic Signals, and Traffic Data.

3. **Relationship Descriptions:**

- Detail each relationship’s nature, cardinality, and optionality.

4. **Justification Document:**

- Explain design choices, including considerations for scalability, real-time data processing, and normalization. Discuss how the design ensures minimal redundancy and maintains data integrity.