CIS 5500: Database and Information Systems
Homework 2: Relational DB Design

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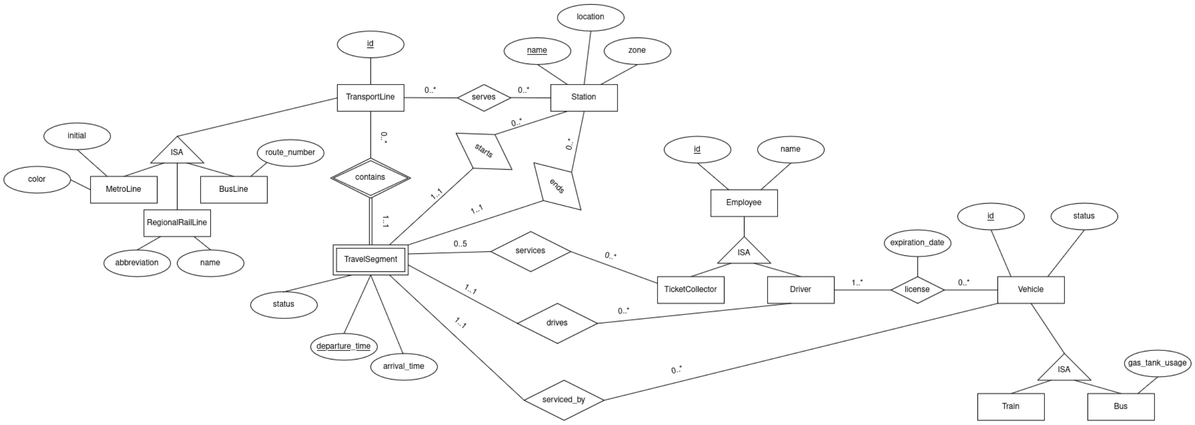
1. **Question 1 (30 points)**

   A. **(20 points)**



   B. **(5 points)**

Ans: A TravelSegment could start or end at a Station that is not served by its associated TransportLine. This would be valid in the ER diagram because there is no constraint requiring the start and end stations of a TravelSegment to be among the stations served by that TransportLine.

To enforce this constraint, we must require that the start and end stations of a TravelSegment appear in the Serves relationship with the same TransportLine. In other words, a TravelSegment may only start and end at stations that are served by its associated TransportLine.

   C. **(5 points)**

Ans: Add an attribute to the relationship `Serves` called `no_of_platforms`. Add an attribute to the Station entity set called `maximum_no_of_platforms`.

We then add a constraint that, for each Station, the sum of `no_of_platforms` across all TransportLines assigned to that Station does not exceed `maximum_no_of_platforms`.

2. **Question 2 (20 points)**

   A. **12 points**

Ans:

```
CREATE TABLE Artists(
ArtistID INT PRIMARY KEY,
Name VARCHAR(50) NOT NULL,
Nationality VARCHAR(50) NOT NULL,
BirthYear INT(4) NOT NULL
);

CREATE TABLE Customers(
CustomerID INT PRIMARY KEY,
Name VARCHAR(50) NOT NULL,
Email VARCHAR(100) NOT NULL
);

CREATE TABLE Artworks(
ArtworkID INT PRIMARY KEY,
OwnerID INT FOREIGN KEY REFERENCES Customers(CustomerID),
CreatorID INT FOREIGN KEY REFERENCES Artists(ArtistID),
Title VARCHAR(50) NOT NULL,
AYear INT(4),
Medium VARCHAR(50)
);

CREATE TABLE Exhibitions(
ExhibitionID INT PRIMARY KEY,
ExhibitionName VARCHAR(100) NOT NULL
);

CREATE TABLE DisplayedIn(
ArtworkID INT,
ExhibitionID INT,
PRIMARY KEY (ArtworkID, ExhibitionID),
FOREIGN KEY (ArtworkID) REFERENCES Artworks(ArtworkID),
FOREIGN KEY (ExhibitionID) REFERENCES
   Exhibitions(ExhibitionID),
StartDate DATE,
EndDate DATE
);
```

B. **4 points**

Ans: We can create an assertion as follows

```
        CREATE ASSERTION exhibition_cardinality
CHECK (
    NOT EXISTS (
        SELECT ExhibitionID
        FROM DisplayedIn
        GROUP BY ExhibitionID
        HAVING COUNT(*) NOT BETWEEN 5 AND 20
    )
);
```

C. **4 points**

Ans: We change the cardinality on the Artists entity set from 0..∗ to 1..∗. We also add the following assertion

```
CREATE ASSERTION artist_has_artwork
CHECK (
  NOT EXISTS (
    SELECT *
    FROM Artists A
    WHERE NOT EXISTS (
      SELECT *
      FROM Artworks W
      WHERE W.CreatorID = A.ArtistID
    )
  )
);
```

3. **Question 3 (40 points)**

A. **4 points**

Ans: No they cannot.
If they did then the functional dependencies PassengerID → PassengerEmail and PassengerEmail → PassengerID would not hold.

B. **4 points**

Ans: Yes. The functional dependency TrainNo → ConductorID only ensures each train has one conductor, but it does not prevent multiple trains from having the same conductor.

C. **6 points**

Ans: The candidate keys are {TrainNo, PassengerID} and {TrainNo, PassengerEmail}. TrainNo determines DepartureDate and ConductorID, PassengerID determines PassengerEmail, and together TrainNo and PassengerID determine SeatNo and BaggageQty, giving all attributes. Since PassengerEmail ↔ PassengerID, replacing PassengerID with PassengerEmail also forms a key.

D. **5 points**

Ans: The dependency TrainNo → DepartureDate, ConductorID violates 3NF because TrainNo is not a superkey and neither DepartureDate nor ConductorID is a member of any candidate key. All other dependencies satisfy 3NF because either the left-hand side is a superkey or the right-hand side attribute is a member of some candidate key.

E. **2 points**

Ans: Yes, the decomposition has a lossless join.

$$R_1 \cap R_2 = \{\text{TrainNo, PassengerID}\},$$

which is a candidate key of R and therefore a superkey of R_2. By the lossless-join condition, a decomposition is lossless if the common attributes form a superkey of at least one of the relations, so the join is lossless.

F. **2 points**

Ans: No, this decomposition does not have a lossless join.

$$R_1 \cap R_2 = \{\text{PassengerID}\},$$

which is neither a superkey of R_1 nor of R_2 (PassengerID alone does not determine DepartureDate or ConductorID, nor SeatNo or BaggageQty), so the lossless-join condition fails.

G. **12 points**

Ans: Applying the 3NF decomposition algorithm to F (already a minimal cover):

- `TrainNo` → `DepartureDate, ConductorID`: create R_1
- `PassengerID` → `PassengerEmail`: create R_2
- `PassengerEmail` → `PassengerID`: R_2 already contains `PassengerEmail, PassengerID` so we skip this functional dependency
- `TrainNo, PassengerID` → `SeatNo, BaggageQty`: create R_3

R_3 contains {`TrainNo, PassengerID`}, a candidate key of R meaning that we do not need any additional relations.

After performing the algorithm we get the following decomposed relations R_i each with with a candidate key and a set of preserved functional dependencies.

- R_1(`TrainNo`, `DepartureDate`, `ConductorID`)
  - **Candidate Key:** {`TrainNo`}
  - **FDs Preserved:** `TrainNo` → `DepartureDate, ConductorID`
- R_2(`PassengerID`, `PassengerEmail`)
  - **Candidate Keys:** {`PassengerID`}, {`PassengerEmail`}
  - **FDs Preserved:** `PassengerID` ↔ `PassengerEmail`
- R_3(`TrainNo`, `PassengerID`, `SeatNo`, `BaggageQty`)
  - **Candidate Key:** {`TrainNo, PassengerID`}
  - **FDs Preserved:** `TrainNo, PassengerID` → `SeatNo, BaggageQty`

H. **5 points**

Ans:

Yes, all three relations are in BCNF. For every $X \to Y$ in F, either $X \to Y$ is trivial or X is a superkey:

- R_1(`TrainNo`, `DepartureDate`, `ConductorID`) with key `TrainNo`. `TrainNo` → `DepartureDate` and `TrainNo`→`ConductorID` have `TrainNo` as LHS, which is a superkey.
- R_2(`PassengerID`, `PassengerEmail`) with keys `PassengerID, PassengerEmail`. `PassengerID` → `PassengerEmail` has superkey LHS, and `PassengerEmail`→`PassengerID` has superkey LHS.
- R_3(`TrainNo`, `PassengerID`, `SeatNo`, `BaggageQty`) with key = `TrainNo, PassengerID`. Both `TrainNo, PassengerID` → `SeatNo` and `TrainNo, PassengerID` → `BaggageQty` have the full key as LHS.