Stage 2: Conceptual and Logical Database Design

Due Mar 4, 2025

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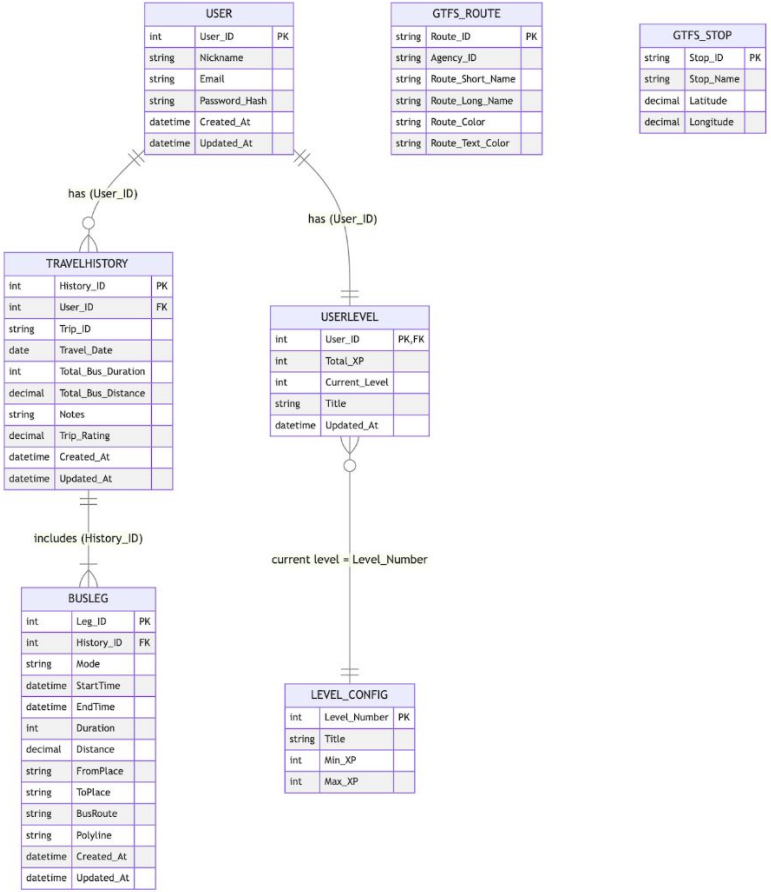
ER Diagram


USER
int User_ID PK
string Nickname
string Email
string Password_Hash
datetime Created_At
datetime Updated_At
GTFS_ROUTE
string Route_ID PK
string Agency_ID
string Route_Short_Name
string Route_Long_Name
string Route_Color
string Route_Text_Color
GTFS_STOP
string Stop_ID PK
string Stop_Name
decimal Latitude
decimal Longitude
has (User_ID)
has (User_ID)
TRAVELHISTORY
int History_ID PK
int User_ID FK
string Trip_ID
date Travel_Date
int Total_Bus_Duration
decimal Total_Bus_Distance
string Notes
decimal Trip_Rating
datetime Created_At
datetime Updated_At
USERLEVEL
int User_ID PK,FK
int Total_XP
int Current_Level
string Title
datetime Updated_At
includes (History_ID)
current level = Level_Number
BUSLEG
int Leg_ID PK
int History_ID FK
string Mode
datetime StartTime
datetime EndTime
int Duration
decimal Distance
string FromPlace
string ToPlace
string BusRoute
string Polyline
datetime Created_At
datetime Updated_At
LEVEL_CONFIG
int Level_Number PK
string Title
int Min_XP
int Max_XP

Assumptions for each entity and relationship

User:
Each user has a unique ID with basic account info (nickname, email, password hash) and timestamps for creation/update.

TravelHistory:
Logs each trip taken by a user, capturing the trip's ID, date, and aggregated bus metrics (duration and distance), plus optional notes and ratings.

BusLeg:
Represents individual bus segments within a trip, detailing start/end times, duration, distance, departure/arrival locations, bus route, and an encoded polyline for mapping.

UserLevel:
Tracks a user's cumulative XP, their current level and title; each user has one level record that can be recalculated by joining with level configuration.

Level_Config:
Defines each level's number and title based on their XP thresholds, serving as a lookup table for the leveling system.

GTFS_Route & GTFS_Stop:
Static reference data from the GTFS feed used to display transit route and stop information.

Relationships & Cardinality:

User (1) ↔ (0..*) TravelHistory: One user can have many travel records.

TravelHistory (1) ↔ (0..*) BusLeg: Each trip may consist of several bus legs.

User (1) ↔ (1) UserLevel: Each user has exactly one level record.

UserLevel (0..*) ↔ (1) Level_Config: A user's current level corresponds to a level configuration entry (many users can share the same level).

GTFS_Route & GTFS_Stop: Serve as static lookup tables for transit information.

Normalization (3NF)

- We noticed that the current database schema violated **3NF** principles, due to transitive dependencies in the **UserLevel** table, between the attributes **Total_XP**, **Current_Level**, and **Title** i.e.:
  - **TotalXP -> Current_Level, Title**
  - But **TotalXP** was not the primary key for the table (**PK** is **User_ID**).
- To fix this issue, we made sure that instead of storing **Current_Level** and **Title** in the **UserLevel** table, we can calculate these values dynamically based on the **Total_XP** when needed.
- To do this, we updated and separated the **UserLevel** logic into:
  - A **UserLevel** table that will store only the user's **User_ID** and **Total_XP**.
  - A **LevelConfig** table that will store standalone level details (such as the **Level_Number, Title, Min_XP, and Max_XP**).
  - A new **UserLevelProgress** table (to link **UserLevel** with **LevelConfig**) that determines which level a user is currently in, based on their **Total_XP.** (Has **User_ID** PK FK to UserLevel.User_ID & **Level_Number** FK to LevelConfig.Level_Number).
  - Now, instead of storing **Current_Level** and **Title** in the **UserLevel** table, we calculate the **Level_Number** based on **Total_XP** and reference it in the **UserLevelProgress** table.

Normalization - 3NF

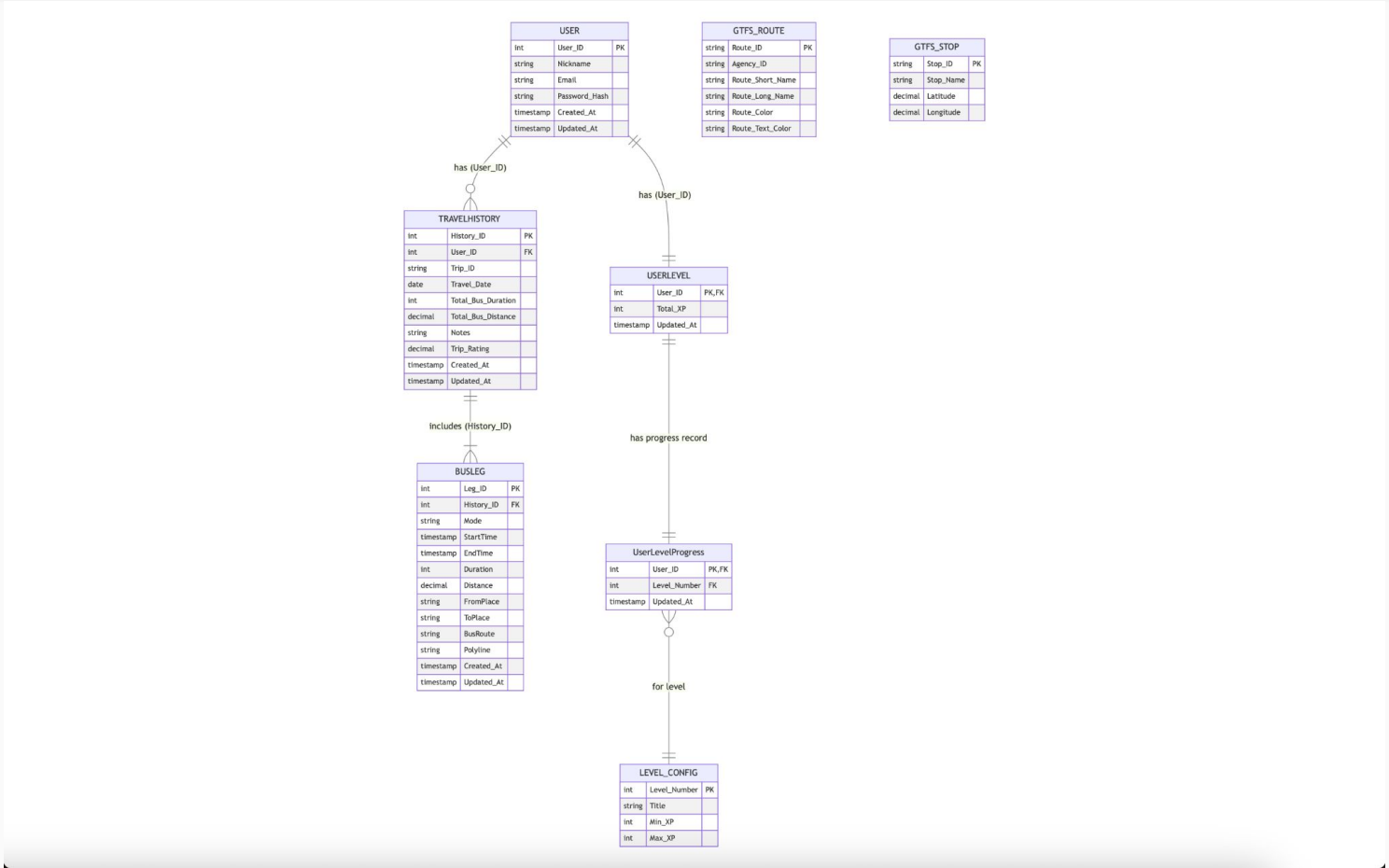
Tables:

- **User**
  - **FDs:** User_ID (PK) -> Nickname, Email, Password_Hash, Created_At, Updated_At
  - Since User_ID is the **primary key**, and this is the only **FD**, **User** table is in **3NF.**
- **GTFS_Route**
  - **FDs:** Route_ID (PK) -> Agency_ID, Route_Short_Name, Route_Long_Name, Route_Color, Route_Text_Color
  - Since Route_ID is the **primary key**, and this is the only **FD**, **GTFS_Route** table is in **3NF**.
- **GTFS_Stop**
  - **FDs:** Stop_ID (PK) -> Stop_Name, Latitude, Longitude
  - Since Stop_ID is the **primary key**, and this is the only **FD**, **GTFS_Stop** table is in **3NF**.
- **Travel_History**
  - **FDs:** History_ID (PK) -> User_ID, Trip_ID, Travel_Date, Total_Bus_Duration, Total_Bus_Distance, Notes, Trip_Rating, Created_At, Updated_At
  - Since History_ID is the **primary key**, and this is the only **FD**, **Travel_History** table is in 3NF.
- **Bus_Leg**
  - **FDs:** Leg_ID (PK) -> History_ID, Mode, StartTime, EndTime, Duration, Distance, FromPlace, ToPlace, BusRoute, Polyline, Created_At, Updated_At
  - Since Leg_ID is the **primary key**, and this is the only **FD**, **Bus_Leg** table is in 3NF.
- **User_Level**
  - **FDs:** User_ID (PK) -> Total_XP, Updated_At
  - Since User_ID is the **primary key**, and this is the only **FD**, **User_Level** table is in **3NF.** *(Prior to normalization, TotalXP -> Current_Level, Title)*
- **User_Level_Progress**
  - **FDs:** User_ID (PK) -> Level_Number, Updated_At
  - Since User_ID is the **primary key**, and this is the only **FD**, **User_Level_Progress** table is in **3NF**.
- **Level_Config**
  - **FDs:** Level_Number -> Title, Min_XP, Max_XP
  - Since Level_Number is the **primary key**, and this is the only **FD**, **Level_Config** table is in **3NF**.

Now, all tables are normalized i.e. adhere to 3NF.

FD: Functional Dependency & PK: Primary Key

ER (3NF Version)



Relational Schema

User(
User_ID: INT [PK],
Nickname: VARCHAR(50),
Email: VARCHAR(100) UNIQUE,
Password_Hash: VARCHAR(255),
Created_At: TIMESTAMP,
Updated_At: TIMESTAMP
)

TravelHistory(
History_ID: INT [PK],
User_ID: INT [FK to User.User_ID],
Trip_ID: VARCHAR(50) UNIQUE,
Travel_Date: DATE,
Total_Bus_Duration: INT,
Total_Bus_Distance: DECIMAL(10,2),
Notes: TEXT,
Trip_Rating: DECIMAL(3,1),
Created_At: TIMESTAMP,
Updated_At: TIMESTAMP
)

BusLeg(
Leg_ID: INT [PK],
History_ID: INT [FK to TravelHistory.History_ID],
Mode: VARCHAR(20),
StartTime: TIMESTAMP,
EndTime: TIMESTAMP,
Duration: INT,
Distance: DECIMAL(10,2),
FromPlace: VARCHAR(100),
ToPlace: VARCHAR(100),
BusRoute: VARCHAR(20),
Polyline: TEXT,
Created_At: TIMESTAMP,
Updated_At: TIMESTAMP
)

UserLevel(
User_ID: INT [PK, FK to User.User_ID],
Total_XP: INT,
Updated_At: TIMESTAMP
)

UserLevelProgress(
User_ID: INT [PK, FK to UserLevel.User_ID],
Level_Number: INT [FK to Level.Level_Number],
Updated_At: TIMESTAMP
)

Level_Config(
Level_Number: INT [PK],
Title: VARCHAR(50),
Min_XP: INT,
Max_XP: INT,
CHECK(Min_XP < Max_XP)
)

GTFS_Route(
Route_ID: VARCHAR(20) [PK],
Agency_ID: VARCHAR(20),
Route_Short_Name: VARCHAR(20),
Route_Long_Name: VARCHAR(100),
Route_Color: VARCHAR(10),
Route_Text_Color: VARCHAR(10)
)

GTFS_Stop(
Stop_ID: VARCHAR(20) [PK],
Stop_Name: VARCHAR(100),
Latitude: DECIMAL(10,6),
Longitude: DECIMAL(10,6)
)

Relational Schema Explanation

- Designed a relational schema to manage users, travel history, and transit data.
- Implemented foreign keys to link users with their trips and trip segments.
- Integrated GTFS transit data for routes and stops to enhance trip tracking.
- Used timestamps and ratings to analyze travel patterns and user experiences.