Database Design Document

Team Introduction – Group_Lab_Team_22:

Name	Responsibility
Aravind Balaji	Conceptual & Logical Design (ERD), Normalization Analysis, Documentation
Akshay Dnyaneshwar Govind	Data Validation, Normalization, Testing, Git Version Control
Pranav Narendrabhai Patel	PL/SQL Procedures, Packages, Triggers, Report Integration

Team combines strengths in data modeling, PL/SQL development, and testing to deliver a robust OLTP system.

---

2. Project Name

Project Title: Commuter Reservation System (CRS)

---

3. Problem Statement

The client's current train ticket booking process is manual and lacks proper data management capabilities, causing inconsistent data, overbooking issues, and operational inefficiencies. There is no real-time seat availability tracking, automated waitlist management, or validation of business rules. A centralized database system is required to:

• Manage trains, schedules, passengers, and reservations effectively.
• Enforce business rules at the database level (1-week advance booking, seat capacity limits, waitlist management).
• Ensure data accuracy through proper constraints and automated validation.
• Support efficient querying for seat availability and booking status in real-time.
• Provide transaction integrity for booking and cancellation operations.
• Enable waitlist promotion upon cancellations with clear audit trails.

---

4. Solution Approach (How the Problem Will Be Tackled & Resolved)

Approach:

• Requirement Gathering: Identify core entities (Train, Schedule, Passenger, Reservation) and business rules (40+5 seat capacity per class, 1-week advance booking, waitlist promotion logic).
• Conceptual Modeling: Create ERD depicting relationships between trains, schedules, passengers, and reservations.
• Logical Modeling: Translate into relational schema with primary/foreign keys, unique constraints, and check constraints.
• Normalization: Apply 1NF–3NF to eliminate redundancy and ensure data integrity.
• Implementation: Build schema with two user roles (Admin, Data User) and PL/SQL packages for booking/cancellation logic; add triggers for waitlist promotion.
• Testing & Reporting: Seed sample data, validate business rules, test exception scenarios, and create views for booking analytics.

Expected Outcome:

• Real-time seat availability tracking with automated capacity management.
• Zero redundancy with strong referential integrity.
• Automated waitlist promotion upon cancellations.
• Operational reports for booking trends, occupancy rates, and revenue analysis.

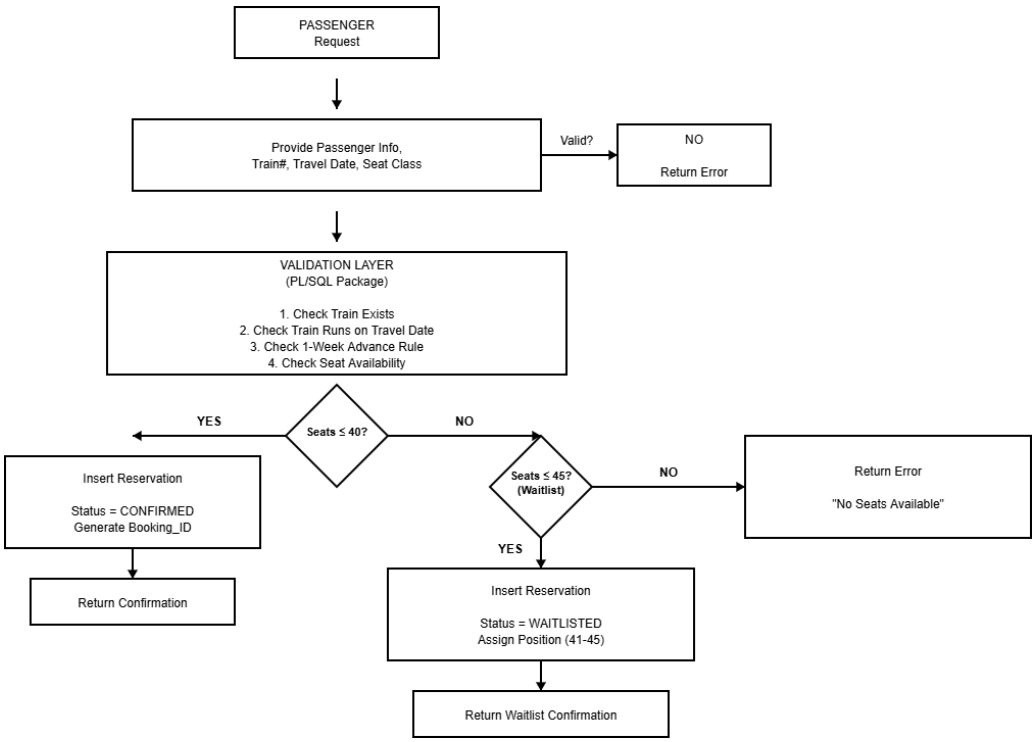
OLTP Justification:

This system follows an Online Transaction Processing (OLTP) architecture. Each user action—booking a ticket, checking seat availability, canceling a reservation, or promoting waitlist passengers—is a short, atomic transaction on a normalized schema with ACID properties. Concurrency is supported via row-level locking and indexes on primary/foreign keys.

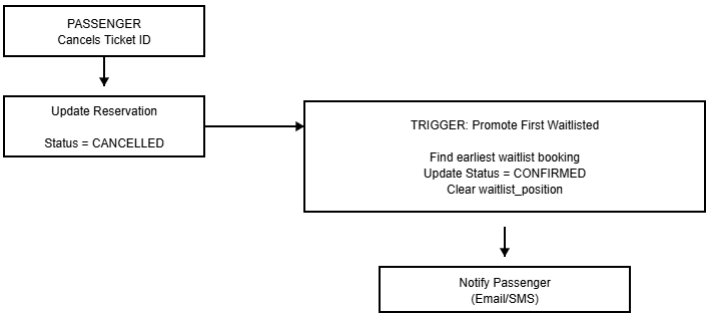
---

5. Workflow Diagram:

Booking workflow:



Cancellation workflow



6. Database Conceptual Model (ER Diagram Description)

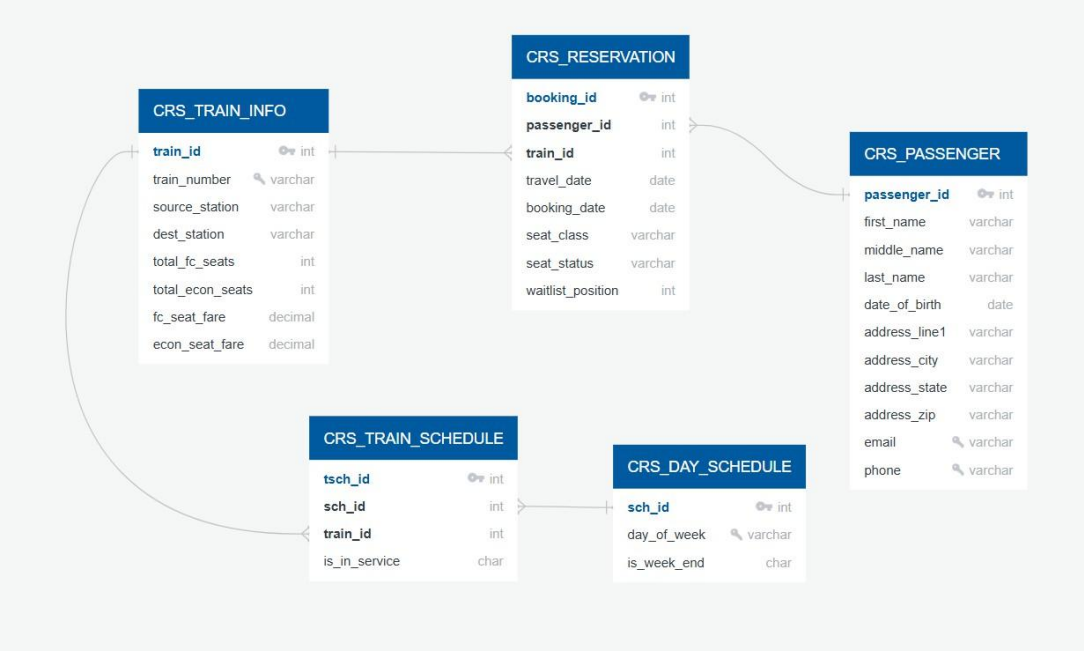
Entities & Attributes:

Entity	Attributes
CRS_TRAIN_INFO	Train_ID (PK), Train_Number (UNIQUE), Source_Station, Dest_Station, Total_FC_Seats, Total_Econ_Seats, FC_Seat_Fare, Econ_Seat_Fare
CRS_DAY_SCHEDULE	Sch_ID (PK), Day_of_Week (UNIQUE), Is_Week_End → removes day/weekend redundancy
CRS_TRAIN_SCHEDULE	TSch_ID (PK), Sch_ID (FK → CRS_DAY_SCHEDULE), Train_ID (FK → CRS_TRAIN_INFO), Is_In_Service → Bridge table for M:N relationship
CRS_PASSENGER	Passenger_ID (PK), First_Name, Middle_Name, Last_Name, Date_of_Birth, Address_Line1, Address_City, Address_State, Address_Zip, Email (UNIQUE), Phone (UNIQUE)
CRS_RESERVATION	Booking_ID (PK), Passenger_ID (FK → CRS_PASSENGER), Train_ID (FK → CRS_TRAIN_INFO), Travel_Date, Booking_Date, Seat_Class, Seat_Status, Waitlist_Position

Key Design Highlights:

- Introduced CRS_DAY_SCHEDULE master table to eliminate day/weekend redundancy → All tables are now in BCNF.
- CRS_TRAIN_SCHEDULE bridge table resolves Many-to-Many relationship between trains and days.
- Single-column primary keys eliminate partial dependencies in all tables.
- Email and Phone are UNIQUE to prevent duplicate passenger records.
- Seat_Status CHECK constraint ensures only valid values: CONFIRMED, WAITLISTED, CANCELLED.
- Seat_Class CHECK constraint allows only: FC (First Class), ECON (Economy).

Entity Relationship (ER) Diagram:



Relationships:

• CRS_TRAIN_INFO ↔ CRS_DAY_SCHEDULE (M:N via CRS_TRAIN_SCHEDULE)

• CRS_TRAIN_INFO → CRS_RESERVATION (1:M)

• CRS_PASSENGER → CRS_RESERVATION (1:M)

---

7. Relational Model (Logical Design)

Table Name	Primary Key	Foreign Keys	Notes / Important Constraints
CRS_TRAIN_INFO	Train_ID	—	Train_Number UNIQUE
CRS_DAY_SCHEDULE	Sch_ID	—	Day_of_Week UNIQUE, Is_Week_End CHECK ('Y', 'N')
CRS_TRAIN_SCHEDULE	TSch_ID	Sch_ID → CRS_DAY_SCHEDULE, Train_ID → CRS_TRAIN_INFO	Is_In_Service CHECK ('Y', 'N')
CRS_PASSENGER	Passenger_ID	—	Email UNIQUE, Phone UNIQUE
CRS_RESERVATION	Booking_ID	Passenger_ID → CRS_PASSENGER, Train_ID → CRS_TRAIN_INFO	Seat_Class CHECK ('FC', 'ECON'), Seat_Status CHECK ('CONFIRMED', 'WAITLISTED', 'CANCELLED')

Detailed Table Specifications:

CRS_TRAIN_INFO

Primary Key: Train_ID

Unique Constraints: Train_Number

Attributes:

Train_ID: System-generated unique identifier

Train_Number: User-facing train identifier (e.g., "TR-101")

Source_Station: Departure station name

Dest_Station: Arrival station name

Total_FC_Seats: Total first class capacity (40)

Total_Econ_Seats: Total economy capacity (40)

FC_Seat_Fare: First class ticket price

Econ_Seat_Fare: Economy ticket price

CRS_DAY_SCHEDULE

Primary Key: Sch_ID

Unique Constraints: Day_of_Week

Check Constraints: Is_Week_End IN ('Y', 'N')

Attributes:

Sch_ID: System-generated unique identifier (1-7)

Day_of_Week: Day name (Monday through Sunday)

Is_Week_End: Weekend flag: 'Y' for Sat/Sun, 'N' for Mon-Fri

Purpose: Provides day reference to eliminate redundancy; contains 7 static rows

CRS_TRAIN_SCHEDULE

Primary Key: TSch_ID

Foreign Keys:

Sch_ID → CRS_DAY_SCHEDULE(Sch_ID)

Train_ID → CRS_TRAIN_INFO(Train_ID)

Check Constraints: Is_In_Service IN ('Y', 'N')

Purpose: Defines which days each train operates (resolves M:N relationship between trains and schedules)

CRS_PASSENGER

Primary Key: Passenger_ID

Unique Constraints: Email, Phone

Attributes:

Passenger_ID: System-generated unique identifier

First_Name, Middle_Name, Last_Name: Name split for atomic values (1NF)

Date_of_Birth: Used for age-based categorization (minor/major/senior)

Address_Line1, Address_City, Address_State, Address_Zip: Address components

Email: Email address (unique across all passengers)

Phone: Phone number (unique across all passengers)

CRS_RESERVATION

Primary Key: Booking_ID

Foreign Keys:

Passenger_ID → CRS_PASSENGER(Passenger_ID)

Train_ID → CRS_TRAIN_INFO(Train_ID)

Check Constraints:

Seat_Class IN ('FC', 'ECON')

Seat_Status IN ('CONFIRMED', 'WAITLISTED', 'CANCELLED')

Business Logic Attributes:

Booking_ID: System-generated unique ticket identifier

Travel_Date: Date of journey (must be ≤ booking_date + 7 days)

Booking_Date: Transaction timestamp

Seat_Class: 'FC' (First Class) or 'ECON' (Economy)

Seat_Status: Booking state (CONFIRMED/WAITLISTED/CANCELLED)

Waitlist_Position: NULL if confirmed, 41-45 if waitlisted

Business Rules:

40 confirmed seats per class → positions 1-40 (conceptual)

5 waitlist seats per class → positions 41-45
On cancellation: First waitlisted ticket promoted to CONFIRMED

8. Normalization and Redundancy Analysis

First Normal Form (1NF):

Rule: All attributes are atomic; no multi-valued columns or repeating groups.

Application:

Passenger name split into First_Name, Middle_Name, Last_Name (atomic values).

Address components separated into Address_Line1, City, State, Zip.

Each booking is a separate row in CRS_RESERVATION.

No arrays or comma-separated values in any column.

Before (Violation):

PASSENGER_BOOKING

Name	Trains_Booked	Phone_Numbers
John Doe	TR-101, TR-102, TR-105	555-1234, 555-56

After (1NF Compliant):

CRS_PASSENGER

Passenger_ID	First_Name	Last_Name	Phone
1	John	Doe	555-1234

CRS_RESERVATION (separate rows)

Booking_ID	Passenger_ID	Train_ID
B001	1	101
B002	1	102
B003	1	105

Second Normal Form (2NF):

Rule: Every non-key attribute is fully dependent on the entire composite key. No partial dependencies.

Application:

All tables use single-column primary keys (Train_ID, Passenger_ID, Booking_ID, TSch_ID).

CRS_RESERVATION stores only Passenger_ID (FK) and Train_ID (FK), not passenger names or train details.

Passenger details stored once in CRS_PASSENGER; train details stored once in CRS_TRAIN_INFO.

Before (Violation - Partial Dependency):

BOOKING_DETAILS (Composite PK: Passenger_ID + Train_ID)

Passenger_ID	Train_ID	Passenger_Name	Train_Route	Seat_Class
1	101	John Doe	NYC-BOS	FC

Problem: Passenger_Name depends only on Passenger_ID (partial dependency)

Problem: Train_Route depends only on Train_ID (partial dependency)

After (2NF Compliant):

CRS_PASSENGER (separate table)

Passenger_ID	First_Name	Last_Name
1	John	Doe

CRS_TRAIN_INFO (separate table)

Train_ID	Source_Station	Dest_Station
101	NEW York	Boston

CRS_RESERVATION (no partial dependencies)

Booking_ID	Passenger_ID	Train_ID	Seat_Class
B001	1	101	FC

Third Normal Form (3NF):

Rule: All transitive dependencies removed. Every non-key attribute depends directly on the primary key.

Application:

Day/weekend information moved to CRS_DAY_SCHEDULE reference table (eliminates day_name → is_weekend transitive dependency).

Train schedule details live in CRS_TRAIN_SCHEDULE bridge table.

Model details referenced via FK in CRS_RESERVATION.

Before (Violation - Transitive Dependency):

RESERVATION_WITH_DAY (Not in 3NF)

Booking_ID	Train_ID	Travel_Date	Day_Name	Is_Weekend
B001	101	2025-12-05	Friday	N
B002	102	2025-12-06	Saturday	Y
B003	103	2025-12-06	Saturday	Y

Problem: Is_Weekend depends on Day_Name, not on Booking_ID (transitive dependency)

After (3NF Compliant):

CRS_DAY_SCHEDULE (reference table)

Sch_ID	Day_of_Week	Is_Week_End
1	Monday	N
2	Tuesday	N
3	Wednesday	N
4	Thursday	N
5	Friday	N
6	Saturday	Y
7	Sunday	Y

CRS_RESERVATION (no transitive dependencies)

Booking_ID	Train_ID	Travel_Date
B001	101	2025-12-05
B002	102	2025-12-06

---

9. Security Design

To ensure data confidentiality, integrity, and controlled access across departments, role-based privileges are implemented at both schema and transaction levels. The Commuter Reservation System (CRS) uses the principle of least privilege — each user role has only the access required to perform its function.

a) User Roles

Role	Description	Example Privileges
DB_ADMIN	Manage database objects, users, and privileges.	CREATE, ALTER, DROP, GRANT, REVOKE
CRS_ADMIN_USER	Schema owner; creates tables, procedures, and grants permissions.	CREATE TABLE, CREATE PROCEDURE, GRANT EXECUTE
CRS_DATA_USER	Execute stored procedures for booking/cancellation operations.	EXECUTE on CRS_BOOKING_PKG, CRS_PASSENGER_PKG
CRS_REPORT_USER	Generates read-only reports and analytics.	SELECT only on BOOKING_REPORT_VIEW, REVENUE_VIEW, OCCUPANCY_VIEW
CRS_SERVICE_USER	Backend application user; calls procedures via API.	EXECUTE on booking/cancellation procedures

b) Data Access Controls

• Role-based access control (RBAC): Each department (Admin, Operations, Reporting) is assigned a unique role to isolate data access.
• Authentication & Authorization: Database users authenticate via role assignment; no direct INSERT/UPDATE/DELETE access to base tables for application users.

• Procedure-level security: CRS_DATA_USER can only execute stored procedures, not directly modify tables. All business logic and validation encapsulated in packages.
• Data encryption: Sensitive information such as passenger email and phone can be protected using Oracle Transparent Data Encryption (TDE).
• Audit triggers: Every booking, cancellation, and waitlist promotion is logged automatically to ensure traceability.

c) Audit and Compliance

• To maintain accountability and data lineage, all transactional operations are recorded in an AUDIT_LOG table.
• Each log entry captures:
(USER_ID, TABLE_NAME, OPERATION, TIMESTAMP, RECORD_ID)

This supports: • Data recovery and rollback of unintended changes.
• Compliance with internal security standards and traceability policies.
• Monitoring of unusual or unauthorized activity (e.g., bulk cancellations).

The combination of role-based privileges, procedure-level security, audit trails, and encryption ensures that the CRS database remains secure, compliant, and reliable. These measures also align with OLTP best practices, where real-time transactions require strict access and integrity control.

---

10. Conclusion

The Commuter Reservation System (CRS) is a fully normalized OLTP database supporting end-to-end train ticket booking operations from reservation to cancellation to waitlist management. It ensures:

• Accurate capacity management with 40 confirmed + 5 waitlist seats per class per train.
• Real-time seat availability tracking through automated counting queries.
• Automated waitlist promotion upon cancellations via database triggers.
• Comprehensive booking history with audit trails for every transaction.

The design enforces referential integrity, reduces redundancy to zero, and provides a scalable foundation for operational reporting. All business rules (1-week advance booking, unique email/phone, seat capacity limits) are enforced at the database level through constraints, procedures, and triggers, ensuring data consistency and reliability for a production-grade train reservation platform.