

Low-Level Design (LLD) for Parking Lot System

I'll explain the complete low-level design for a parking lot system with detailed Java implementation.

1. Requirements Gathering

Functional Requirements:

1. Multiple floors with multiple parking spots per floor
2. Different types of parking spots (Compact, Large, Handicapped, Motorcycle)
3. Different types of vehicles (Car, Truck, Van, Motorcycle)
4. Entry and exit panels at each floor
5. Payment system with hourly rates
6. Parking spot allocation strategy
7. Parking ticket generation
8. Display available spots

Non-Functional Requirements:

1. System should be scalable
 2. High availability
 3. Thread-safe for concurrent operations
-

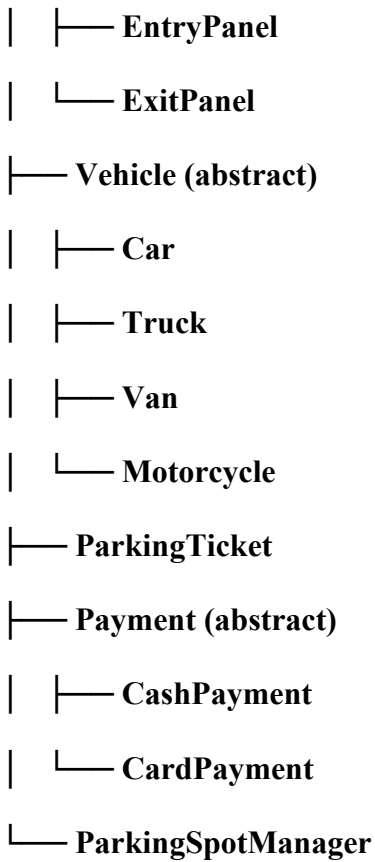
2. Core Entities and Classes

Class Diagram Overview:

ParkingLot (Singleton)

└── ParkingFloor (multiple)

| └── ParkingSpot (multiple)



3. Detailed Implementation

Step 1: Enums and Constants

java

// Enum for Vehicle Types

```
enum VehicleType {  
    CAR,  
    TRUCK,  
    VAN,  
    MOTORCYCLE  
}
```

// Enum for Parking Spot Types

```
enum ParkingSpotType {  
  
    COMPACT,  
  
    LARGE,  
  
    HANDICAPPED,  
  
    MOTORCYCLE  
  
}
```

// Enum for Parking Spot Status

```
enum ParkingSpotStatus {  
  
    AVAILABLE,  
  
    OCCUPIED,  
  
    RESERVED  
  
}
```

// Enum for Payment Status

```
enum PaymentStatus {  
  
    PENDING,  
  
    COMPLETED,  
  
    FAILED,  
  
    REFUNDED  
  
}
```

// Enum for Payment Method

```
enum PaymentMethod {  
  
    CASH,  
  
    CREDIT_CARD,  
  
    DEBIT_CARD,  
  
    UPI  
  
}
```

Step 2: Vehicle Classes

java

// Abstract Vehicle class

```
abstract class Vehicle {  
  
    private String licensePlate;  
  
    private VehicleType vehicleType;  
  
  
  
  
  
  
  
  
  
    public Vehicle(String licensePlate, VehicleType vehicleType) {  
  
        this.licensePlate = licensePlate;  
  
        this.vehicleType = vehicleType;  
  
    }  
  
  
  
  
  
  
  
  
  
    public String getLicensePlate() {  
  
        return licensePlate;  
  
    }  
  
}
```

```
public VehicleType getVehicleType() {  
    return vehicleType;  
}  
}
```

// Concrete Vehicle classes

```
class Car extends Vehicle {  
    public Car(String licensePlate) {  
        super(licensePlate, VehicleType.CAR);  
    }  
}
```

```
class Truck extends Vehicle {  
    public Truck(String licensePlate) {  
        super(licensePlate, VehicleType.TRUCK);  
    }  
}
```

```
class Van extends Vehicle {  
    public Van(String licensePlate) {  
        super(licensePlate, VehicleType.VAN);  
    }  
}
```

```
}
```

```
class Motorcycle extends Vehicle {  
    public Motorcycle(String licensePlate) {  
        super(licensePlate, VehicleType.MOTORCYCLE);  
    }  
}
```

Step 3: Parking Spot Classes

java

// Abstract ParkingSpot class

```
abstract class ParkingSpot {  
    private String spotId;  
    private ParkingSpotType spotType;  
    private ParkingSpotStatus status;  
    private Vehicle vehicle;  
  
    public ParkingSpot(String spotId, ParkingSpotType spotType) {  
        this.spotId = spotId;  
        this.spotType = spotType;  
        this.status = ParkingSpotStatus.AVAILABLE;  
        this.vehicle = null;  
    }  
}
```

```
public synchronized boolean isAvailable() {  
    return status == ParkingSpotStatus.AVAILABLE;  
}
```

```
public synchronized boolean assignVehicle(Vehicle vehicle) {  
    if (isAvailable() && canFitVehicle(vehicle)) {  
        this.vehicle = vehicle;  
        this.status = ParkingSpotStatus.OCCUPIED;  
        return true;  
    }  
    return false;  
}
```

```
public synchronized boolean removeVehicle() {  
    if (status == ParkingSpotStatus.OCCUPIED) {  
        this.vehicle = null;  
        this.status = ParkingSpotStatus.AVAILABLE;  
        return true;  
    }  
    return false;  
}
```

// Abstract method to check if vehicle can fit

```
protected abstract boolean canFitVehicle(Vehicle vehicle);
```

```
// Getters
```

```
public String getSpotId() { return spotId; }
```

```
public ParkingSpotType getSpotType() { return spotType; }
```

```
public ParkingSpotStatus getStatus() { return status; }
```

```
public Vehicle getVehicle() { return vehicle; }
```

```
}
```

```
// Concrete Parking Spot classes
```

```
class CompactSpot extends ParkingSpot {
```

```
    public CompactSpot(String spotId) {
```

```
        super(spotId, ParkingSpotType.COMPACT);
```

```
    }
```

```
@Override
```

```
protected boolean canFitVehicle(Vehicle vehicle) {
```

```
    // Compact spots can fit motorcycles and cars
```

```
    return vehicle.getVehicleType() == VehicleType.MOTORCYCLE ||
```

```
        vehicle.getVehicleType() == VehicleType.CAR;
```

```
}
```

```
}
```



```
class LargeSpot extends ParkingSpot {  
  
    public LargeSpot(String spotId) {  
  
        super(spotId, ParkingSpotType.LARGE);  
  
    }  
  
    @Override  
  
    protected boolean canFitVehicle(Vehicle vehicle) {  
  
        // Large spots can fit any vehicle  
  
        return true;  
  
    }  
}  
  
class HandicappedSpot extends ParkingSpot {  
  
    public HandicappedSpot(String spotId) {  
  
        super(spotId, ParkingSpotType.HANDICAPPED);  
  
    }  
  
    @Override  
  
    protected boolean canFitVehicle(Vehicle vehicle) {  
  
        // Handicapped spots can fit cars  
  
        return vehicle.getVehicleType() == VehicleType.CAR;  
  
    }  
}
```

```
class MotorcycleSpot extends ParkingSpot {  
    public MotorcycleSpot(String spotId) {  
        super(spotId, ParkingSpotType.MOTORCYCLE);  
    }  
  
    @Override  
    protected boolean canFitVehicle(Vehicle vehicle) {  
        // Motorcycle spots only fit motorcycles  
        return vehicle.getVehicleType() == VehicleType.MOTORCYCLE;  
    }  
}
```

Step 4: Parking Ticket

```
java  
  
import java.time.LocalDateTime;  
import java.time.Duration;  
  
class ParkingTicket {  
    private String ticketId;  
    private Vehicle vehicle;  
    private ParkingSpot parkingSpot;  
    private LocalDateTime entryTime;  
    private LocalDateTime exitTime;
```

```
private double amount;
```

```
private PaymentStatus paymentStatus;
```

```
public ParkingTicket(String ticketId, Vehicle vehicle, ParkingSpot parkingSpot) {
```

```
    this.ticketId = ticketId;
```

```
    this.vehicle = vehicle;
```

```
    this.parkingSpot = parkingSpot;
```

```
    this.entryTime = LocalDateTime.now();
```

```
    this.paymentStatus = PaymentStatus.PENDING;
```

```
}
```

```
public void markExit() {
```

```
    this.exitTime = LocalDateTime.now();
```

```
    this.amount = calculateAmount();
```

```
}
```

```
private double calculateAmount() {
```

```
    if (exitTime == null) {
```

```
        return 0.0;
```

```
    }
```

```
// Calculate parking duration in hours
```

```
    Duration duration = Duration.between(entryTime, exitTime);
```

```
long hours = duration.toHours();
```

```
// If less than 1 hour, charge for 1 hour
```

```
if (hours < 1) {
```

```
    hours = 1;
```

```
}
```

```
// Rate based on vehicle type
```

```
double hourlyRate = getHourlyRate();
```

```
return hours * hourlyRate;
```

```
}
```

```
private double getHourlyRate() {
```

```
    switch (vehicle.getVehicleType()) {
```

```
        case MOTORCYCLE:
```

```
            return 5.0;
```

```
        case CAR:
```

```
            return 10.0;
```

```
        case VAN:
```

```
            return 15.0;
```

```
        case TRUCK:
```

```
            return 20.0;
```

```
        default:
```

```
        return 10.0;

    }

}

public void updatePaymentStatus(PaymentStatus status) {

    this.paymentStatus = status;

}
```

// Getters

```
public String getTicketId() { return ticketId; }

public Vehicle getVehicle() { return vehicle; }

public ParkingSpot getParkingSpot() { return parkingSpot; }

public LocalDateTime getEntryTime() { return entryTime; }

public LocalDateTime getExitTime() { return exitTime; }

public double getAmount() { return amount; }

public PaymentStatus getPaymentStatus() { return paymentStatus; }

}
```

Step 5: Payment Classes

java

// Abstract Payment class

```
abstract class Payment {

    private String paymentId;

    private double amount;
```

```
private PaymentStatus status;
```

```
private PaymentMethod method;
```

```
private LocalDateTime paymentTime;
```

```
public Payment(String paymentId, double amount, PaymentMethod method) {
```

```
    this.paymentId = paymentId;
```

```
    this.amount = amount;
```

```
    this.method = method;
```

```
    this.status = PaymentStatus.PENDING;
```

```
}
```

```
public abstract boolean processPayment();
```

```
protected void markCompleted() {
```

```
    this.status = PaymentStatus.COMPLETED;
```

```
    this.paymentTime = LocalDateTime.now();
```

```
}
```

```
protected void markFailed() {
```

```
    this.status = PaymentStatus.FAILED;
```

```
}
```

```
// Getters
```

```
public String getPaymentId() { return paymentId; }

public double getAmount() { return amount; }

public PaymentStatus getStatus() { return status; }

public PaymentMethod getMethod() { return method; }

}
```

// Concrete Payment classes

```
class CashPayment extends Payment {

    private double cashReceived;

    public CashPayment(String paymentId, double amount, double cashReceived) {

        super(paymentId, amount, PaymentMethod.CASH);

        this.cashReceived = cashReceived;

    }

}
```

@Override

```
public boolean processPayment() {

    if (cashReceived >= getAmount()) {

        markCompleted();

        System.out.println("Cash payment processed. Change: $" +

            (cashReceived - getAmount()));

        return true;

    }

}
```

```
markFailed();

System.out.println("Insufficient cash!");

return false;

}

}
```

```
class CardPayment extends Payment {

    private String cardNumber;

    private String cvv;

    public CardPayment(String paymentId, double amount,

        PaymentMethod method, String cardNumber, String cvv) {

        super(paymentId, amount, method);

        this.cardNumber = cardNumber;

        this.cvv = cvv;

    }

}
```

@Override

```
public boolean processPayment() {

    // Simulate card processing

    if (validateCard()) {

        markCompleted();

        System.out.println("Card payment processed successfully!");

    }

}
```



```

        return true;
    }

    markFailed();

    System.out.println("Card payment failed!");

    return false;
}

private boolean validateCard() {

    // Simulate card validation

    return cardNumber != null && cvv != null && cvv.length() == 3;

}
}

```

Step 6: Parking Floor

java

```

import java.util.*;

class ParkingFloor {

    private int floorNumber;

    private List<ParkingSpot> parkingSpots;

    private Map<ParkingSpotType, List<ParkingSpot>> spotsByType;

    public ParkingFloor(int floorNumber) {

        this.floorNumber = floorNumber;
    }
}

```

```
this.parkingSpots = new ArrayList<>();
```

```
this.spotsByType = new HashMap<>();
```

```
// Initialize spotsByType map
```

```
for (ParkingSpotType type : ParkingSpotType.values()) {
```

```
    spotsByType.put(type, new ArrayList<>());
```

```
}
```

```
}
```

```
public void addParkingSpot(ParkingSpot spot) {
```

```
    parkingSpots.add(spot);
```

```
    spotsByType.get(spot.getSpotType()).add(spot);
```

```
}
```

```
public synchronized ParkingSpot findAvailableSpot(Vehicle vehicle) {
```

```
// Strategy: Try to find the most appropriate spot type first
```

```
List<ParkingSpotType> preferredTypes = getPreferredSpotTypes(vehicle);
```

```
for (ParkingSpotType type : preferredTypes) {
```

```
    for (ParkingSpot spot : spotsByType.get(type)) {
```

```
        if (spot.isAvailable() && spot.assignVehicle(vehicle)) {
```

```
            return spot;
```

```
}
```

```
    }  
}  
return null;  
}
```

```
private List<ParkingSpotType> getPreferredSpotTypes(Vehicle vehicle) {  
    List<ParkingSpotType> types = new ArrayList<>();  
  
    switch (vehicle.getVehicleType()) {  
        case MOTORCYCLE:  
            types.add(ParkingSpotType.MOTORCYCLE);  
            types.add(ParkingSpotType.COMPACT);  
            types.add(ParkingSpotType.LARGE);  
            break;  
        case CAR:  
            types.add(ParkingSpotType.COMPACT);  
            types.add(ParkingSpotType.LARGE);  
            break;  
        case VAN:  
        case TRUCK:  
            types.add(ParkingSpotType.LARGE);  
            break;  
    }  
}
```

```

    return types;
}

public Map<ParkingSpotType, Integer> getAvailableSpotCount() {
    Map<ParkingSpotType, Integer> counts = new HashMap<>();

    for (ParkingSpotType type : ParkingSpotType.values()) {
        int count = 0;

        for (ParkingSpot spot : spotsByType.get(type)) {
            if (spot.isAvailable()) {
                count++;
            }
        }

        counts.put(type, count);
    }

    return counts;
}

public int getFloorNumber() {
    return floorNumber;
}

```

```
public List<ParkingSpot> getParkingSpots() {  
    return parkingSpots;  
}  
}
```

Step 7: Entry and Exit Panels

java

```
class EntryPanel {  
    private String panelId;  
    private int floorNumber;  
  
    public EntryPanel(String panelId, int floorNumber) {  
        this.panelId = panelId;  
        this.floorNumber = floorNumber;  
    }  
  
    public ParkingTicket generateTicket(Vehicle vehicle, ParkingSpot spot) {  
        String ticketId = "TKT-" + System.currentTimeMillis();  
        ParkingTicket ticket = new ParkingTicket(ticketId, vehicle, spot);  
  
        System.out.println("=== PARKING TICKET ===");  
        System.out.println("Ticket ID: " + ticketId);  
        System.out.println("Vehicle: " + vehicle.getLicensePlate());  
    }  
}
```

```
System.out.println("Spot: " + spot.getSpotId());
```

```
System.out.println("Entry Time: " + ticket.getEntryTime());
```

```
System.out.println("=====");
```

```
return ticket;
```

```
}
```

```
public String getPanelId() { return panelId; }
```

```
public int getFloorNumber() { return floorNumber; }
```

```
}
```

```
class ExitPanel {
```

```
private String panelId;
```

```
private int floorNumber;
```

```
public ExitPanel(String panelId, int floorNumber) {
```

```
    this.panelId = panelId;
```

```
    this.floorNumber = floorNumber;
```

```
}
```

```
public boolean processExit(ParkingTicket ticket) {
```

```
    ticket.markExit();
```

```

System.out.println("\n=== EXIT SUMMARY ===");

System.out.println("Ticket ID: " + ticket.getTicketId());

System.out.println("Vehicle: " + ticket.getVehicle().getLicensePlate());

System.out.println("Entry Time: " + ticket.getEntryTime());

System.out.println("Exit Time: " + ticket.getExitTime());

System.out.println("Amount Due: $" + ticket.getAmount());

System.out.println("=====\n");

return true;
}

public boolean processPayment(ParkingTicket ticket, Payment payment) {
    if (payment.processPayment()) {
        ticket.updatePaymentStatus(PaymentStatus.COMPLETED);

        ticket.getParkingSpot().removeVehicle();

        System.out.println("Payment successful! You may exit now.");

        return true;
    }

    System.out.println("Payment failed! Please try again.");

    return false;
}

public String getPanelId() { return panelId; }

```

```
    public int getFloorNumber() { return floorNumber; }  
}
```

Step 8: Parking Lot (Singleton)

java

```
import java.util.*;
```

```
import java.util.concurrent.ConcurrentHashMap;
```

```
class ParkingLot {
```

```
    private static ParkingLot instance;
```

```
    private String name;
```

```
    private String address;
```

```
    private List<ParkingFloor> floors;
```

```
    private Map<String, ParkingTicket> activeTickets;
```

```
// Private constructor for Singleton
```

```
    private ParkingLot(String name, String address) {
```

```
        this.name = name;
```

```
        this.address = address;
```

```
        this.floors = new ArrayList<>();
```

```
        this.activeTickets = new ConcurrentHashMap<>();
```

```
    }
```

```
// Singleton getInstance method
```



```
public static synchronized ParkingLot getInstance(String name, String address) {  
    if (instance == null) {  
        instance = new ParkingLot(name, address);  
    }  
    return instance;  
}
```

```
public void addFloor(ParkingFloor floor) {  
    floors.add(floor);  
}
```

```
public synchronized ParkingTicket parkVehicle(Vehicle vehicle) {  
    // Find available spot across all floors  
    for (ParkingFloor floor : floors) {  
        ParkingSpot spot = floor.findAvailableSpot(vehicle);  
        if (spot != null) {  
            // Generate ticket from entry panel  
            EntryPanel entryPanel = new EntryPanel(  
                "ENTRY-" + floor.getFloorNumber(),  
                floor.getFloorNumber()  
            );  
            ParkingTicket ticket = entryPanel.generateTicket(vehicle, spot);  
            activeTickets.put(ticket.getTicketId(), ticket);  
        }  
    }  
}
```

```
System.out.println("Vehicle parked successfully on Floor " +
```

```
    floor.getFloorNumber());
```

```
    return ticket;
```

```
}
```

```
}
```

```
System.out.println("Sorry! Parking lot is full.");
```

```
return null;
```

```
}
```

```
public synchronized boolean unparkVehicle(String ticketId, Payment payment) {
```

```
    ParkingTicket ticket = activeTickets.get(ticketId);
```

```
    if (ticket == null) {
```

```
        System.out.println("Invalid ticket!");
```

```
        return false;
```

```
}
```

```
// Process exit
```

```
ExitPanel exitPanel = new ExitPanel("EXIT-1", 1);
```

```
exitPanel.processExit(ticket);
```

// Process payment

```
if (exitPanel.processPayment(ticket, payment)) {
```

```
    activeTickets.remove(ticketId);
```

```
    return true;
```

```
}
```

```
return false;
```

```
}
```

```
public void displayAvailability() {
```

```
    System.out.println("\n=== PARKING LOT AVAILABILITY ===");
```

```
    System.out.println("Parking Lot: " + name);
```

```
    for (ParkingFloor floor : floors) {
```

```
        System.out.println("\nFloor " + floor.getFloorNumber() + ":");
```

```
        Map<ParkingSpotType, Integer> counts = floor.getAvailableSpotCount();
```

```
        for (Map.Entry<ParkingSpotType, Integer> entry : counts.entrySet()) {
```

```
            System.out.println("  " + entry.getKey() + ": " +
```

```
                entry.getValue() + " spots available");
```

```
        }
```

```
}
```

```
System.out.println("=====\n");
```

```
}
```

```
public ParkingTicket getTicket(String ticketId) {  
    return activeTickets.get(ticketId);  
}  
}
```

Step 9: Demo and Testing

java

```
public class ParkingLotDemo {  
    public static void main(String[] args) {  
        // Initialize Parking Lot  
        ParkingLot parkingLot = ParkingLot.getInstance(  
            "Downtown Parking",  
            "123 Main Street"  
        );  
  
        // Create floors and spots  
        setupParkingLot(parkingLot);  
  
        // Display initial availability  
        parkingLot.displayAvailability();  
  
        // Test Case 1: Park a car
```

```
System.out.println("--- Test Case 1: Park a Car ---");
```

```
Vehicle car1 = new Car("ABC-1234");
```

```
ParkingTicket ticket1 = parkingLot.parkVehicle(car1);
```

```
// Test Case 2: Park a motorcycle
```

```
System.out.println("\n--- Test Case 2: Park a Motorcycle ---");
```

```
Vehicle bike1 = new Motorcycle("XYZ-5678");
```

```
ParkingTicket ticket2 = parkingLot.parkVehicle(bike1);
```

```
// Test Case 3: Park a truck
```

```
System.out.println("\n--- Test Case 3: Park a Truck ---");
```

```
Vehicle truck1 = new Truck("TRK-9999");
```

```
ParkingTicket ticket3 = parkingLot.parkVehicle(truck1);
```

```
// Display availability after parking
```

```
parkingLot.displayAvailability();
```

```
// Simulate some time passing (for testing payment calculation)
```

```
simulateTimeDelay();
```

```
// Test Case 4: Unpark the car with cash payment
```

```
System.out.println("\n--- Test Case 4: Unpark Car (Cash) ---");
```

```
if (ticket1 != null) {
```

```
Payment cashPayment = new CashPayment(
    "PAY-" + System.currentTimeMillis(),
    ticket1.getAmount(),
    50.0
);
parkingLot.unparkVehicle(ticket1.getTicketId(), cashPayment);
}

// Test Case 5: Unpark motorcycle with card payment
System.out.println("\n--- Test Case 5: Unpark Motorcycle (Card) ---");
if (ticket2 != null) {
    Payment cardPayment = new CardPayment(
        "PAY-" + System.currentTimeMillis(),
        ticket2.getAmount(),
        PaymentMethod.CREDIT_CARD,
        "1234-5678-9012-3456",
        "123"
    );
    parkingLot.unparkVehicle(ticket2.getTicketId(), cardPayment);
}

// Display final availability
parkingLot.displayAvailability();
```

```
}
```

```
private static void setupParkingLot(ParkingLot parkingLot) {
```

```
    // Create 3 floors
```

```
    for (int i = 1; i <= 3; i++) {
```

```
        ParkingFloor floor = new ParkingFloor(i);
```

```
        // Add different types of spots to each floor
```

```
        // 10 Compact spots
```

```
        for (int j = 1; j <= 10; j++) {
```

```
            floor.addParkingSpot(
```

```
                new CompactSpot("F" + i + "-C" + j)
```

```
            );
```

```
        }
```

```
        // 10 Large spots
```

```
        for (int j = 1; j <= 10; j++) {
```

```
            floor.addParkingSpot(
```

```
                new LargeSpot("F" + i + "-L" + j)
```

```
            );
```

```
        }
```

```
        // 5 Motorcycle spots
```

```
for (int j = 1; j <= 5; j++) {  
    floor.addParkingSpot(  
        new MotorcycleSpot("F" + i + "-M" + j)  
    );  
}
```

// 2 Handicapped spots

```
for (int j = 1; j <= 2; j++) {  
    floor.addParkingSpot(  
        new HandicappedSpot("F" + i + "-H" + j)  
    );  
}
```

```
parkingLot.addFloor(floor);  
}  
}
```

```
private static void simulateTimeDelay() {  
    try {  
        Thread.sleep(2000); // Wait 2 seconds  
    } catch (InterruptedException e) {  
        e.printStackTrace();  
    }  
}
```



```
}  
  
}
```

4. Key Design Principles Used

1. SOLID Principles

- **Single Responsibility:** Each class has one reason to change
- **Open/Closed:** Open for extension (new vehicle/spot types) but closed for modification
- **Liskov Substitution:** Subclasses can replace parent classes
- **Interface Segregation:** Specific interfaces for specific needs
- **Dependency Inversion:** Depend on abstractions, not concrete classes

2. Design Patterns

- **Singleton Pattern:** ParkingLot has only one instance
- **Factory Pattern:** Could be added for creating different spot/vehicle types
- **Strategy Pattern:** Different payment methods
- **Template Method:** Payment processing

3. Thread Safety

- Synchronized methods for concurrent access
- ConcurrentHashMap for active tickets

5. Extensibility Points

The design can be easily extended to add:

1. **Reservation System:** Add a reservation class
2. **Electric Vehicle Charging:** Add EVChargingSpot
3. **Monthly Pass:** Add subscription-based parking

4. **Admin Dashboard:** Add admin operations
5. **Notification System:** SMS/Email notifications
6. **Parking History:** Track all parking events