

**Texas Tech University**  
**Department of Computer Science**

**CS5373 - Software Modeling and Design**

**Term Project: Secure Highway Toll System**

Your group has been assigned to a project to design a distributed and concurrent system for a Secure Highway Toll System. Your group has been given the Requirements Model for the Highway Toll System, which describes in a Use Case Model, which consists of a description of the actors and use cases that fully define the system. Each use case is described in terms of the actors and their interactions with the system.

The system is to be developed in two phases as follows:

**Term Project: Phase I**

For Phase 1 of the project, you are required to develop an analysis model of the system. In particular:

- a) Develop a software system context class model depicted on a class diagram showing how the system interfaces to the external environment.
- b) Develop a static model showing the entity classes in the system, attributes of the classes, and the relationships between them.
- c) Develop interaction diagrams (one for each use case), using either communication diagrams or sequence diagrams, depicting the sequence of interactions among the objects participating in each use case. Describe briefly the objects participating in each interaction diagram, identifying the object structuring criteria used.
- d) For use cases involving entering and leaving the highway, show the statechart as well as the interaction diagram for each use case. In addition, show the alternative paths on both the interaction diagrams and statecharts. Make sure that each statechart is consistent with the appropriate interaction diagram.
- e) Develop message sequence descriptions, describing the object interactions on each interaction diagram depicted in (1c) above.

*State any assumptions you make.*

## **Term Project: Phase II**

For Phase II of the project, you are required to develop a Design Model for the Highway Toll System. In particular:

- a) Develop an integrated communication diagram(s) showing all the objects and message interfaces in the system.
- b) Define the software architecture, (depicted on a concurrent communication diagram), showing the clients and server of the system. Define the message communication interfaces between the clients and server.
- c) Define the task architecture (depicted on concurrent communication diagrams) showing the concurrent tasks in each subsystem and the interfaces between them. Describe the criteria used for task structuring. Define the message communication interfaces.
- d) Define the information hiding classes in the system. Define the operations of each class. Define the class interface specifications for the information hiding classes in the system.
- e) Develop a task interface specification and a task behavior specification for each concurrent task in the system, showing how each task responds to the inputs it receives.

*State any assumptions you make.*

## **HIGHWAY TOLL SYSTEM: PROBLEM DESCRIPTION**

A major metropolitan region has constructed a series of toll roads. Each toll road has a series of fixed checkpoints consisting of one or more tollbooths, which serve as collection points for the toll fees. Customers who use the toll road may pay the tolls by using a transponder placed in their vehicle or by paying with cash or credit cards at selected tollbooths.

Customers wishing to use automated transponders purchase these transponders through the regional toll center. This regional center maintains customer accounts in a database including owner and vehicle information, account balance, and history. Customer purchasing a transponder must pay ahead for toll fees by credit card. Customers are notified by email or postal mail when the accounts are running low and if the account is out of funds. Accounts are reduced by the toll amount incurred at the end of each trip. The toll amount to be paid depends on the length of the trip and category of the vehicle.

For access onto the toll highway, there are two kinds of toll booth.

1. High-Speed - Transponder only with no barrier.
2. Ticket issuing booth with barrier. The driver presses a button to receive the ticket.

To leave the toll highway, there are two kinds of toll booth.

1. High-Speed - Transponder only with no barrier.
2. Human operated full service booth (transponder, credit card, pay by cash) with barrier.

All tollbooths consist of an operational light to indicate whether the tollbooth is available for use; a vehicle-approaching sensor (placed 50 feet in front of the tollbooth); a vehicle-passed sensor; a traffic light to indicate whether the vehicle has been authorized to pass through the tollbooth; a transponder sensor; a camera; and an alarm. Additionally, all tollbooths other than the high-speed / transponder-only lanes contain a vehicle barrier that is raised and lowered to enforce payment. Exit tollbooths also have a display to indicate the required toll. Full service tollbooths have a card reader device, which can read both tollbooth issued tickets and credit cards, as well as an operator who collects the appropriate toll and authorizes a car to pass. After the driver inserts the ticket into the card reader, the entry point and toll amount (which are read off the ticket) will be displayed on the operator's display. (Note that transponders may be used in any tollbooth.)

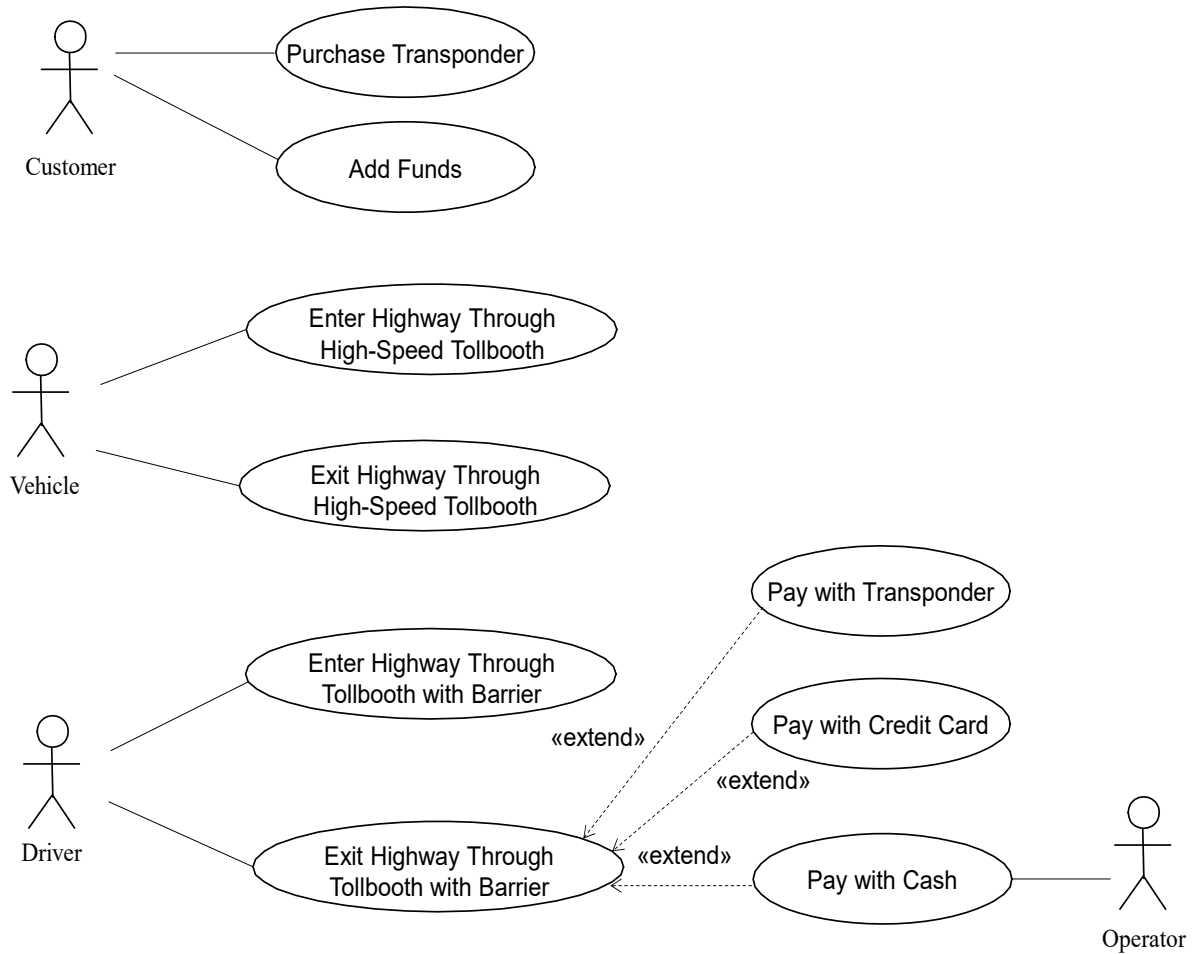
The traffic light at each tollbooth is initially red and, if present, the barrier is lowered. When a vehicle approaches the tollbooth, the vehicle sensor detects the vehicle's presence. If the transponder sensor detects a valid transponder in the approaching vehicle, the system switches the light to green and opens the barrier, if present. In the case of a successful credit card payment or toll payment to the operator, the light will be turned to green and the barrier will be raised. The traffic light is returned to red and the barrier lowered after the car passes. If a vehicle passes through the tollbooth while the traffic light is still red, an alarm sounds, the video camera photographs the license plate, and a bill is issued to the vehicle owner with the image.

Customers not possessing a transponder (or having insufficient funds on their transponder) must use a full-service tollbooth. In each of these cases, the toll is calculated based on the time, day, and checkpoint location. For full-service tollbooths, the customer can pay by credit card or pay an operator who manually collects the required toll and authorizes the vehicle to pass. When the required toll has been collected, the barrier is raised and the light is changed to green.

Security requirements have been described in each use case description. You can add additional security requirements to the use cases if necessary.

## Use Cases for Highway Toll System

### Use case model



## Use case descriptions

**Use Case Name:** Purchase Transponder

**Actor:** Customer

**Summary:** Customer applies for a new transponder account online.

**Precondition:** None

**Description:**

1. Customer accesses transponder account registration website and selects “Create new account”.
2. System requests customer information.
3. Customer enters name, login name and password, email, address, phone number and the driver license number, then submits information.
4. System creates a new user account and registers user.
5. System displays the account information (account id, customer name) to the customer.

**Alternatives:**

- **Missing information:** If customer omits required information, such as name, system displays error message and requests missing information.

**Security Requirements:**

- Customer information should not be released to the unauthorized parties.

**Postcondition:** A transponder account has been created for the customer.

**Use Case Name:** Add funds

**Actor:** Customer

**Summary:** Customer adds funds to transponder account.

**Precondition:** Customer account exists.

**Description:**

1. Customer accesses transponder account registration website and selects “Add funds to account”.
2. System prompts customer for user name and password.
3. User enters user name and password.
4. System requests amount of funds to add, in multiples of \$10.00.
5. Customer enters amount.
6. System requests billing information.
7. Customer enters billing information, such as credit card number and expiration date.
8. Customer submits amount and billing information.
9. System displays receipt.

**Alternatives:**

- **Invalid user name or password:** If the user name or password is invalid, system displays error message and prompts for user name and password.
- **Invalid Credit card:** If credit card is invalid, system displays error message and requests updated billing information.

**Security Requirements:**

- Customer’s account password should not be released to unauthorized parties.
- Customer’s billing information should not be released to unauthorized parties.

**Postcondition:** Funds have been added to the transponder account.

**Use Case Name:** Enter Highway through High Speed Tollbooth

**Actor:** Vehicle

**Summary:** Vehicle enters highway through high speed tollbooth and system records time, day, location, and vehicle type

**Precondition:** Tollbooth is open and the traffic light at the tollbooth is red

**Description:**

1. Vehicle approaches high speed tollbooth.
2. System detects vehicle's presence.
3. System detects a valid transponder in the approaching vehicle.
4. System records time of entry, day, location, and transponder id.
5. System switches traffic light to green.
6. Vehicle passes through the tollbooth.
7. System detects that the vehicle has departed and switches traffic light to red.

**Alternatives:**

- **No transponder / Invalid transponder:** If the system detects a vehicle that has no transponder, or an invalid transponder, the traffic light remains red and an alarm sounds. A video camera photographs the vehicle's license plate and a bill is issued to the vehicle owner with the image.

**Security Requirements:**

- The time of entry, day location, and transponder id are related to customer's privacy and should not be released to unauthorized parties.
- The time of entry, day location, and transponder id should not be changed maliciously.

**Postcondition:** The time, day, and location have been recorded for the vehicle.

**Use Case Name:** Enter Highway through Tollbooth with Barrier

**Actor:** Driver

**Summary:** Vehicle enters highway through tollbooth with barrier and a ticket is issued to driver with the time and day of entry and location.

**Precondition:** Tollbooth is open, the traffic light at the tollbooth is red, and the barrier is down

**Description:**

1. Vehicle approaches tollbooth with barrier.
2. Driver presses button to receive a ticket.
3. System prints out a ticket with the time and day of entry and location.
4. System raises the barrier and switches traffic light to green.
5. Vehicle leaves the tollbooth.
6. System detects that the vehicle has departed, lowers the barrier, and switches traffic light to red.

**Alternatives:**

- **Low on tickets:** If the machine is low on tickets an alert is sent to the regional toll center.

**Security Requirements:**

- The time and day of entry and location should not be released to unauthorized parties.

**Postcondition:** A ticket has been issued to the driver.

**Use Case Name:** Exit highway Through High Speed Toll Booth

**Actor:** Vehicle

**Summary:** Vehicle exits highway through high speed toll booth and system reduces account by toll amount incurred at end of trip.

**Precondition:** Tollbooth is open and the traffic light at the tollbooth is red

**Description:**

1. Vehicle approaches high speed toll booth.
2. System detects vehicle's presence.
3. System detects a valid transponder in the approaching vehicle.
4. System records time of exit, day, location, and transponder id.
5. System calculates toll based on start time and day, exit time and day, start location, and exit location.
6. System deducts toll amount from customer's account.
7. System switches traffic light to green.
8. Vehicle leaves the tollbooth.
9. System detects that the vehicle has departed and switches traffic light to red.

**Alternatives:**

- **No transponder / Invalid transponder:** If the system detects a vehicle that has no transponder, or an invalid transponder, the traffic light remains red and an alarm sounds. A video camera photographs the vehicle's license plate and a bill is issued to the vehicle owner with the image.
- **Insufficient funds:** If the system determines that there are insufficient funds in the account, additional charges are billed to the customer's account.

**Security Requirements:**

- The time and day of entry and location should not be released to unauthorized parties.

**Postcondition:** The toll has been charged to the transponder account.

**Use Case Name:** Exit Highway through Tollbooth with Barrier

**Actor:** Driver

**Summary:** Vehicle exits highway through tollbooth with barrier.

**Precondition:** Tollbooth is open and the traffic light at the tollbooth is red.

**Description:**

1. Vehicle approaches tollbooth.
2. System detects vehicle's presence.
3. Driver enters ticket into ticket reader.
4. System calculates charges based on entry and exit times, entry and exit locations.
5. System displays charges and prompts for type of payment (cash, credit card, or transponder account).
6. <payment>
7. System raises the barrier and switches the traffic light green.
8. Vehicle passes through the tollbooth.
9. System detects that the vehicle has departed, lowers the barrier, and switches the traffic light red

**Alternatives:**

- None.

**Postcondition:** The customer has paid the toll and the vehicle has passed through the toll booth.



**Use Case Name:** Pay with credit card

**Actor:** Customer

**Dependency:** Extends Exit Highway through Tollbooth with Barrier use case

**Summary:** Customer pays toll charges with a credit card.

**Precondition:** Charges are calculated and displayed for the approaching vehicle.

**Description:**

1. Customer selects “Pay with credit card”.
2. Customer scans credit card.
3. System requests authorization for charges on credit card.
4. Credit card authorization center authorizes credit card payment.
5. System prints credit card receipt.

**Alternatives:**

- **Charges not authorized:** If charges are not authorized on the credit card, system prompts for another form of payment.

**Security Requirements:**

- Credit card information should not be released to unauthorized parties.

**Postcondition:** The credit card has been charged with the toll amount.

**Use Case Name:** Pay with transponder account

**Actor:** Customer

**Dependency:** Extends Exit Highway through Tollbooth with Barrier use case

**Summary:** Customer pays toll charges with transponder account.

**Precondition:** Charges are calculated and displayed for the approaching vehicle.

**Description:**

1. Customer selects “Pay with transponder account”.
2. System detects a valid transponder on the vehicle.
3. System deducts toll amount from customer’s account and prints receipt.

**Alternatives:**

- **No transponder / Invalid transponder:** If there is no transponder on vehicle, or transponder is invalid, system prompts for another form of payment.
- **Insufficient funds:** If the system determines that there are insufficient funds in the account, additional charges are billed to the customer’s account.

**Postcondition:** The transponder account has been charged with the toll amount.

**Use Case Name:** Pay with cash

**Actors:** Customer, Operator

**Dependency:** Extends Exit Highway through Tollbooth with Barrier use case

**Summary:** Customer gives cash to an operator to pay for the toll charges.

**Precondition:** Charges are calculated and displayed for the approaching vehicle.

**Description:**

1. Customer selects “Pay with cash”.
2. Customer gives cash to the operator.

3. The operator gives the customer change, if necessary, and issues a receipt to the customer.
4. The operator commands the system to raise the barrier.

**Alternatives:**

- **Insufficient cash or Cannot pay:** If the customer doesn't have enough money, the operator bills the customer using the information on the customer's driver's license.

**Postcondition:** The customer has paid the toll charges and has been issued a receipt.