



# 407 Express Toll Route

## Use Case Model using UCM & Domain Model

September 28, 2012

### Problem Statement

The 407 Express Toll Route is a highway that runs east-west just north of Toronto, and was one of the largest road construction projects in the history of Canada. The road uses a highly modern Electronic Toll Collection (ETC) system constructed by Raytheon.

The ETR technology allows motorists to pass through toll routes without stopping or even opening a window. To make this happen, each highway entry and exit point is equipped with a *gantry* (see figure 1).

### Processing Registered Vehicles

The most cost-efficient way to pay for highway use is to open an account with the 407 ETR system. Accounts can be personal or linked to a company. In either case, billing information (name and address) is saved with the account. Once an account is created, vehicles can be registered with it. Registered vehicles require a small electronic tag, called a transponder (see figure 2), to be attached to the windshield behind the rear-view mirror. Transponders are leased for a small monthly fee. The registration includes the vehicle details.

The system automatically records the entry and exit of vehicles, and creates a transaction for each trip. This is done in the following way. When the vehicle enters the highway, it passes under the overhead gantry. The hardware devices of a gantry are shown in figure 3.

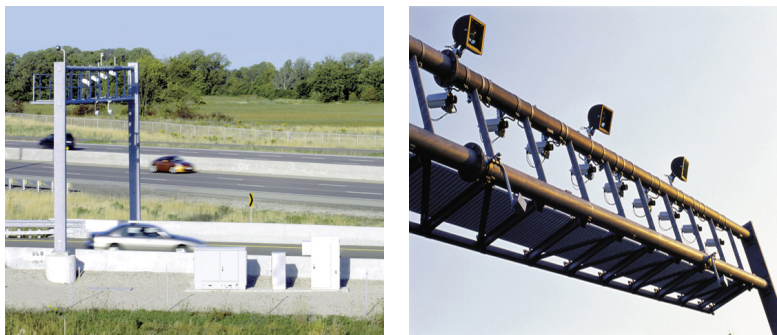


Figure 1: The 407 Entry / Exit Gantries



Figure 2: A Transponder

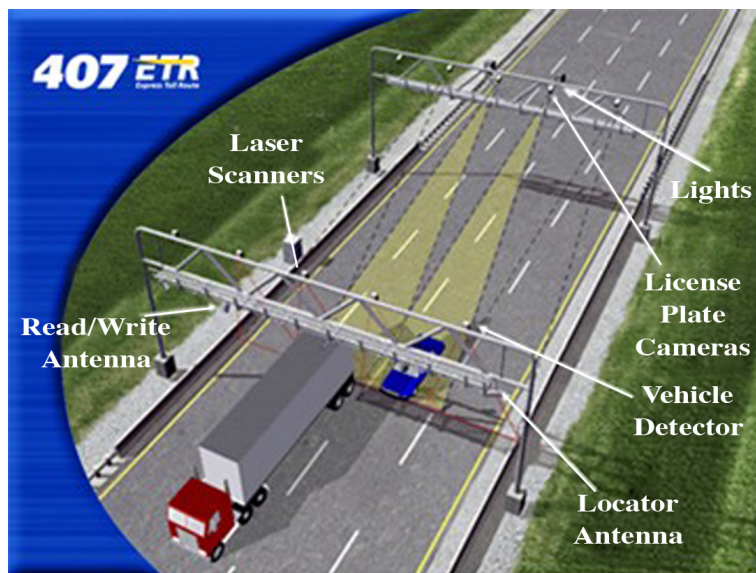


Figure 3: An Entry / Exit Gantry

The locator antennae determine if the vehicle is equipped with a transponder. Next, the read / write antennae read the account number from the transponder and the point of entry, time and date is recorded.

In addition, as a vehicle passes under the gantries, the system uses laser scanners to determine the class of vehicle (e.g. light vehicle, heavy single unit vehicle, heavy multiple unit vehicle). It does this by measuring the height, width and depth of each approaching vehicle. A check is made to verify that the class of vehicle corresponds to the one registered for this particular transponder.

The same process occurs when the vehicle exits the highway. The entry and exit data are then matched and the transponder account holder is debited. When the route is exited, the transponder gives a green signal followed by four short beeps to indicate a successful completion of the transaction.

## Processing Unregistered Vehicles

Transponders are mandatory for heavy vehicles, i.e. vehicles with a gross weight of 5,000 kg. However, light vehicles can use the 407 ETR without registering.

When a motorist without a transponder enters the highway and passes under the two tolling gantries, the system triggers a set of digital cameras to take pictures of the rear number plate of the vehicle from different angles. In order to get good images, a set of lights are turned on before the images are taken. The lights automatically adjust their intensity to ensure the best conditions for taking an image of the number plate. At the same time, the laser scanners are activated to classify the vehicle and tell the toll collection system whether to charge for a passenger or commercial vehicle. The owner of the vehicle is identified by electronic access to government records.

The cameras and lights have been tested to ensure accuracy, even in blizzards and rainstorms. However, if the video correlation and image processing fails to determine the license plate with sufficient probability, a human operator has to look at the pictures to make the call.

## Payment

Registered car owners, registered companies, and motorist that used the highway, receive an invoice in the mail at the end of the month containing the trips of all of the vehicles registered with their account. The price of each trip is calculated based on the time of day and distance traveled. In case automatic number plate recognition is used, an additional video toll charge (of \$3.50) is applied per trip.

Cheating motorists (for instance, motorists using a transponder with an unregistered vehicle, or heavy vehicles taking the highway without a transponder) are fined, and refusal to pay invoices or fines results in plate denial, meaning that a debtor cannot renew the license plate of his cars or obtain a new license plate from the government until all tolls and fees have been paid.

## Hardware / Software Decisions

The software to be developed has to interface with the hardware devices of the gantry. The development of the software running on the transponders is going to be outsourced to a different company, and hence does not have to be considered for this assignment.

## Use Case Model

The use case model of the 407 ETR has already been established. The use cases and their relationships are summarized in figure 4. The individual descriptions of each use case are shown below.

### UseHighway Use Case

**Use Case:** UseHighway

**Scope:** 407 ETR System

**Level:** Summary

**Intention in Context:** The intention of the Driver is to use the 407 ETR highway on a regular basis.

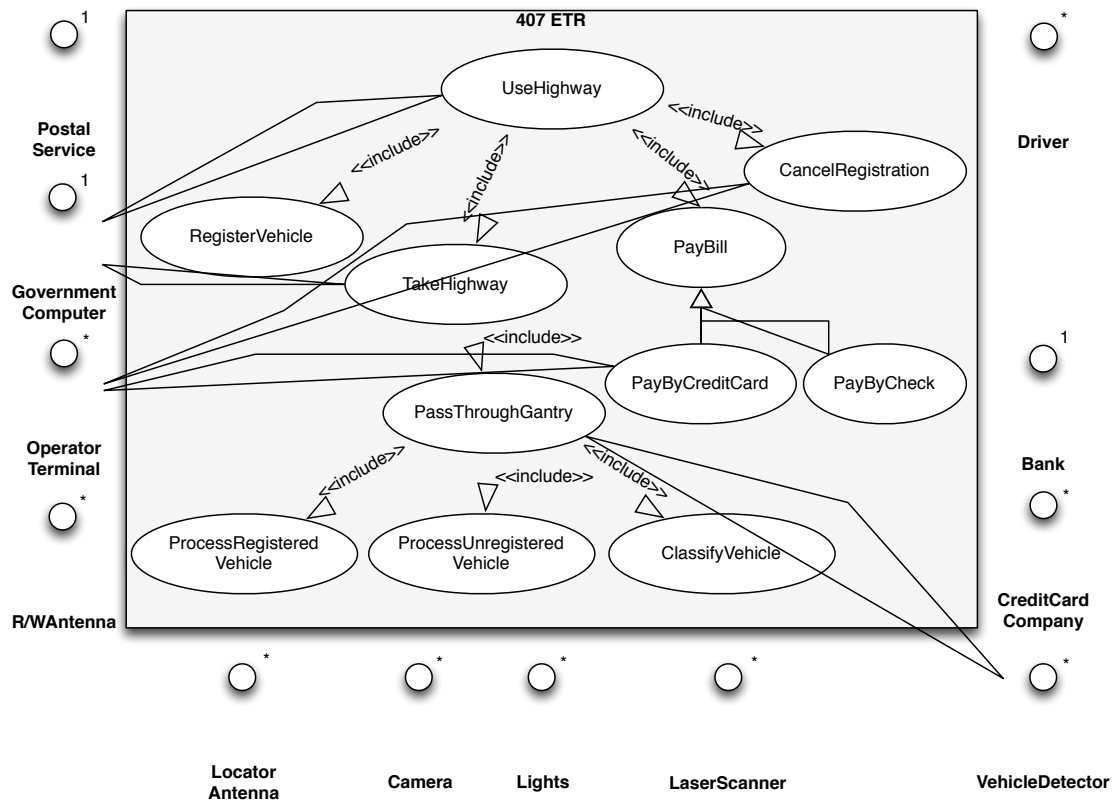


Figure 4: 407 ETR Use Case Diagram

**Multiplicity:** One Driver can only drive one vehicle at a time on the highway. However, different Drivers can use the highway simultaneously.

**Primary Actor:** Driver

**Secondary Actor:** GovernmentComputer

**Main Success Scenario:**

1. *Driver* registers vehicle.

*Step 2-4 are repeated once a month as long as the vehicle is registered.*

*Step 2 can be repeated any number of times per month.*

2. *Driver* takes highway.

3. At the end of the month, *System* sends bill to *Driver*.

4. *Driver* pays bill.

5. *Driver* cancels registration.

**Extensions:**

1a. *Driver* uses highway without registering vehicle. Use case continues at step 2.

4a. *Driver* does not pay bill for 3 consecutive months.

4a.1. *System* informs *GovernmentComputer* of refusal to pay the bill. Use case continues at step 2.

## RegisterVehicle Use Case

**Use Case:** RegisterVehicle

**Scope:** 407 ETR System

**Level:** User Goal

**Intention in Context:** The goal of the *Driver* is to register a vehicle with the system, which involves opening an account and linking a transponder to it.

**Multiplicity:** A driver registers his vehicles one at a time. However, the system should be able to handle multiple simultaneous registrations done by different drivers.

**Primary Actor:** Driver

**Secondary Actor:** OperatorTerminal, GovernmentComputer, PostalService

**Main Success Scenario:**

*The Driver interacts with the System by calling an Operator.*

1. *Driver* provides *System* with personal data and vehicle information.
2. *System* acknowledges opening of a new account for the *Driver*.
3. *System* sends vehicle information to *GovernmentComputer* for verification.
4. *GovernmentComputer* notifies *System* that vehicle information is correct.
5. *System* assigns a new transponder to the vehicle, and informs *Postal Service* to deliver the transponder to the *Driver*.
6. *Driver* installs and tests transponder.
7. *Driver* notifies the *System* of successful installation of the transponder.

**Extensions:**

- 2a. Driver already has an account with the system. Use case continues at step 3.
- 4a. Exception{GovernmentComputerUnavailable}. Use case ends in failure.
- 6a. Transponder installation and testing fails. *Driver* notifies *System* of the problem. Use case continues at step 5.
- 7a. *Driver* forgets to acknowledge installation and simply starts using the transponder on the highway. Use case ends in success.

## TakeHighway Use Case

**Use Case:** TakeHighway

**Scope:** 407 ETR System

**Level:** User Goal

**Intention in Context:** The intention of the *Driver* is to drive a vehicle from one location to another by taking the 407 ETR highway.

**Multiplicity:** One *Driver* can only drive one vehicle at a time on the highway. However, different Drivers can take the highway simultaneously.

**Primary Actor:** Driver

**Secondary Actor:** RWAntenna, GovernmentComputer, OperatorTerminal

**Main Success Scenario:**

1. *Driver* enters highway, passing through gantry.
2. *Driver* exits highway, passing through gantry.
3. *System* retrieves the driver's vehicle record based on trip information\*.
4. *System* determines the amount owed based on the trip information and adds the transaction to the vehicle's records.
5. *System* informs *Driver* by sending a signal to the *RWAntenna* of successful completion of transaction.

**Extensions:**

- 3a. Vehicle is unregistered and does not have a record yet.
  - 3a.1. *System* sends licence plate information to *GovernmentComputer*.
  - 3a.2. *GovernmentComputer* sends vehicle information and owner's address to *System*.
  - 3a.2a. Exception{GovernmentComputerUnavailable}: use case ends in failure.
  - 3a.3. *System* creates a new vehicle record. Use case continues at step 4.
- 3b. Vehicle is unregistered and licence plate is unrecognizeable.
  - 3b.1. *System* displays pictures on *OperatorTerminal*.
  - 3b.2. *OperatorTerminal* sends licence plate information to *System*. Use case continues at step 3.
  - 3b.2a. Exception{OperatorTerminalFailure}: use case ends in failure.
- 4a. Exit unsuccessful.
  - 4a.1a. If entry was successful, minimum trip charge is added to vehicle's records. Use case ends in success.
  - 4a.1b. If entry was unsuccessful as well, use case ends in failure.
- 4b. Entry unsuccessful.

- 4b.1a. If exit was successful, minimum trip charge is added to vehicle's records. Use case continues at step 4.
- 5a. Vehicle is not registered. Use case ends in success.
- 5b. Exception{RWAntennaFailure}: use case ends in success.

**\*Trip Information Details:** A complete trip information record includes entry and exit time and place, measured and obtained vehicle classification, transponder account or licence plate information or licence plate images.

## PassThroughGantry Use Case

**Use Case:** PassThroughGantry

**Scope:** 407 ETR System

**Level:** Sub-Function

**Intention in Context:** The *Driver* passes through a entry or exit gantry as part of his trip.

**Multiplicity:** One *Driver* can only drive one vehicle at a time through a gantry. However, different Drivers can pass through the same or different gantries simultaneously.

**Primary Actor:** Driver

**Secondary Actor:** VehicleDetector

**Main Success Scenario:**

1. *VehicleDetector* informs *System* that vehicle is approaching entry gantry.

*Steps 2 and 3 are performed in any order or in parallel.*

2. *System* processes registered vehicle or processes unregistered vehicle.
3. *System* classifies vehicle.
4. *System* records entry time and vehicle information for the trip.

**Extensions:**

- 1a. Exception{DetectorFailure}

- 1a.1. *System* processes registered vehicle. Use case continues at step 3.

- 4a. Processing was unsuccessful. Use case ends in failure.

- 4b. Classification was unsuccessful. Use case ends in success.

## ProcessRegisteredVehicle Use Case

**Use Case:** ProcessRegisteredVehicle

**Scope:** 407 ETR System

**Level:** Sub-Function

**Intention in Context:** The System communicates with the transponder to identify the approaching vehicle.

**Multiplicity:** The System must be able to process multiple registered vehicles simultaneously.

**Primary Actor:** N/A

**Secondary Actor:** LocatorAntenna, R/WAntenna

**Main Success Scenario:**

1. *LocatorAntenna* notifies *System* that it detected an approaching vehicle with transponder.
2. *System* asks *R/WAntenna* to obtain account information from transponder.
3. *R/WAntenna* informs *System* of account information.
4. *System* records account information for the trip.

**Extensions:**

- 1a. The approaching vehicle does not have a transponder. Use case ends in failure.

- 1b. Exception{LocatorAntennaFailure}: use case ends in failure.

- (2-3)a. Exception{RWAntennaFailure}: use case ends in failure.

- 3a. *R/WAntenna* is unable to obtain account information. Use case ends in failure.

## ProcessUnregisteredVehicle Use Case

**Use Case:** ProcessUnregisteredVehicle

**Scope:** 407 ETR System

**Level:** Sub-Function

**Intention in Context:** The System wants to identify the approaching vehicle using the licence plate information.

**Multiplicity:** The System must be able to process multiple unregistered vehicles simultaneously.

**Primary Actor:** N/A

**Secondary Actor:** Cameras, Lights

**Main Success Scenario:**

1. *System* turns on the *Lights*.
2. *System* triggers the *Cameras*.
3. *Cameras* send images to *System*.

**Extensions:**

- 2a. Exception{LightFailure} Use case continues at step 2.
- 3a. Exception{CameraFailure} Use case ends in failure.

## ClassifyVehicle Use Case

**Use Case:** ClassifyVehicle

**Scope:** 407 ETR System

**Level:** Sub-Function

**Intention in Context:** The System wants to classify the approaching vehicle as light vehicle, heavy single unit vehicle, or heavy multiple unit vehicle.

**Multiplicity:** The System must be able to classify multiple vehicles simultaneously.

**Primary Actor:** N/A

**Secondary Actor:** LaserScanner

**Main Success Scenario:**

1. *System* activates *LaserScanner*.
2. *LaserScanner* sends vehicle dimensions to *System*.
3. *System* classifies vehicle and records classification in trip information.

**Extensions:**

2a. Exception{LaserScannerFailure} System records classification failure in trip information. Use case ends in failure.

## PayByCreditCard Use Case

**Use Case:** PayByCreditCard

**Scope:** 407 ETR System

**Level:** User Goal

**Intention in Context:** The goal of the Driver is pay for his trip by credit card.

**Multiplicity:** Every driver pays for his trips once a month. The system must support concurrent payments of different drivers, be it by credit card or by check.

**Primary Actor:** Driver

**Secondary Actor:** OperatorTerminal, CreditCardCompany

**Main Success Scenario:**

*Driver interacts with System by calling an Operator.*

1. *Operator* provides *System* with credit card information.
2. *System* contacts *CreditCardCompany* to validate credit.
3. *CreditCardCompany* notifies *System* of successful validation.
4. *System* notifies *Operator* of success.

**Extensions:**

- 2a. Exception{CreditCardCompanyUnavailable}: *System* notifies *Operator*. Use case ends in failure.
- 3a. Exception{InsufficientCredit}: *System* notifies *Operator*. Use case ends in failure.

## PayByCheck Use Case

**Use Case:** PayByCheck

**Scope:** 407 ETR System

**Level:** User Goal

**Intention in Context:** The goal of the Driver is pay for his trip by check.

**Multiplicity:** Every driver pays for his trips once a month. The system must support concurrent payments of different drivers, be it by credit card or by check.

**Primary Actor:** Driver

**Secondary Actor:** OperatorTerminal

**Main Success Scenario:**

*Driver sends check to Operator.*

1. *Operator* notifies *System* that check has been received.

*Operator* cashes check with Bank.

2. *Bank* notifies *System* that check has been cleared.

**Extensions:**

2a. Exception{BouncedCheck}: *System* notifies *Driver*. Use case ends in failure.

## CancelRegistration Use Case

**Use Case:** CancelRegistration

**Scope:** 407 ETR System

**Level:** User Goal

**Intention in Context:** The goal of the Driver is to unregister a vehicle and potentially cancel his account with the 407 ETR system.

**Multiplicity:** A driver unregisters a vehicle one at a time. The system should be able to handle multiple concurrent unregistrations of different drivers.

**Primary Actor:** Driver

**Secondary Actor:** OperatorTerminal

**Main Success Scenario:**

*Driver interacts with System by calling an Operator.*

1. *Operator* notifies *System* that *Driver* wants to cancel his registration for a vehicle.

2. *System* marks vehicle registration as suspended and does not charge monthly fees anymore.

*Driver sends transponder to Operator.*

3. *Operator* notifies *System* that transponder has been received.

4. *System* cancels vehicle registration.

5. If Driver has no vehicles registered with the system anymore, *System* cancels driver account.

**Extensions:**

3a. Exception{TransponderUsed}: *System* reactivates registration. Use case ends in failure.

