Electronic Toll Collection (ETC) evolved in an attempt to speed up traffic flow and minimize queuing at toll plazas. The basic definition of ETC is a toll system that allows drivers to pay the toll without paying cash at the toll plaza. Thus, methods of payment for ETC systems include SmartCards, prepaid accounts, monthly charged accounts, as well as systems that automatically debit money directly from the user’s bank account. ETC systems offer the toll operator the advantage of lower labor costs—no one is needed to collect the tolls—in addition to the advantage it provides the motorists via elimination of queuing and faster travel.

**EZ PASS**

A well known example of an ETC system in the United States is the E-ZPass system present in the northeast corridor. The original E-ZPass system, installed in 1993, required that drivers whose vehicles were equipped with the E-ZPass transponder stop or slow to less than 5 mph in the toll booth, while the system verified the transponder and recorded the transaction. This system was still significantly faster than the traditional methods of paying via cash or tokens. On the Garden State Parkway, a toll road in New Jersey utilizing ETC technology, average collection time for E-ZPass is three seconds compared to 9.6 for cash and 4.6 for token based transactions (Peters & Kramer, 2003). While this represents a significant time savings and thereby increases the total number of vehicles that can pass through a toll plaza, this ETC technology is not nearly as advanced as ETC technology that is in place today in several parts of the world, although the basic components of the systems are quite similar.

**FREE FLOW TOLLING**

The new ETC technology is also referred to as free flow tolling, because the system allows cars to pass through the toll gantries without deviating from typical highway speeds. This technology, in combination with OCR that allows the system to read the license plates of vehicles without transponders, creates a system where there is no longer a need for a toll plaza, and their accompanying congestion. Since free flow ETC means that travel plazas are no longer necessary, it is possible to install tolling equipment on virtually any road, no matter the amount of space available. This is a picture of a tolling point on a free flow tolling highway. As can be seen, there are no lane or speed restrictions that accompany the large tolling plazas often seen in the United States. Additionally, the tolling points do not require any additional land to operate.

The removal of congestion and land availability concerns allow planners to further implement tolling for a variety of purposes including raising funds to pay for maintenance costs, raising funds to pay for the cost of the roadway, variable pricing to influence traffic patterns (i.e. discouraging travel during peak periods with higher toll fees), and finally promoting more efficient lane use by allowing single occupant vehicles access to high occupancy vehicle lanes by paying a toll.

**How It Works**

How ETC works is that each vehicle is equipped with a transponder or Dedicated Short Range Communication (DSRC) device. When the vehicle nears a toll point, an overhead antenna sends a signal to the DSRC. Then, depending on the type of DSRC employed, the signal is either reflected with slight modification, or a different signal is sent back to the control tower. The signal modification is device unique allowing the system to identify the user by the signal. The user information is then relayed from the toll site to a central computer system that processes all toll transactions. Depending on the type of DSRC employed, the signal is either reflected with slight modification, or a different signal is sent back to the control tower. The signal modification is device unique allowing the system to identify the user by the signal. The user information is then relayed from the toll site to a central computer system that processes all toll transactions. Depending on the type of DSRC employed, the signal is either reflected with slight modification, or a different signal is sent back to the control tower.

The Raytheon system was first implemented with the opening of the 407 Express Toll Route (ETR) in Toronto in October of 1997. The 407 ETR is a closed...
access toll road, meaning that there are toll gantries at every entrance and exit of the road. What is unique about the 407 ETR is that there are no cash transactions whatsoever. In addition to the typical ETC transaction which entails an information exchange between the vehicle DSRC and roadside communication equipment, the system utilizes cameras equipped with Optical Character Recognition [OCR] that are capable of photographing and identifying the license plates of all cars passing through the system without transponders. This allows the operators of the 407 to send a bill to the address of the vehicle owner each time it passes through the toll. This system allows vehicles to pass through tolls at full highway speed. Since there is no slowing in order to pay the toll, there is no additional congestion or pollution caused by tolling. These two facts help to alleviate concerns raised about the true cost of toll collection on our highways.

For example, Peters and Kramer 2003 Transportation Quarterly article sets out to demonstrate the true costs of toll collection— including administrative, compliance, and environmental costs. In this study, Peters and Kramer find that the additional pollution costs caused by tolling on the Garden State Parkway [GSP] in New Jersey were equivalent to 8.3 percent of the revenue collected and 22.3 percent of the total cost of the system. On the GSP, additional pollutants are created because both vehicles equipped with DSRC and those vehicles that are going to pay by cash or token have to slow to a near or complete stop and then reaccelerate to highway speed. This acceleration produces more pollutants than if the cars did not stop to pay the toll. However, by creating a toll system in which vehicles can pass through the gantries at normal highway speed, often called free flow tolling, the 407 ETR’s tolling system does not cause additional pollution, and thereby makes tolling a more efficient means of revenue collection.

In order to identify cars passing through the toll gantry without the transponder, the Raytheon system employed on the 407 ETR uses two laser beam scanners placed above the roadway. In addition to identifying all vehicles passing through the roadway, the system also classifies each vehicle into a specific tolling category. This allows the operators of the ETR to maximize their revenues, by charging longer vehicles a higher toll. This is also more equitable—longer vehicles are also more likely to be heavier thus causing more wear and tear than typical vehicles. Returning to vehicle identification, the lasers note each vehicle as it breaks the barrier. The computers then match this set of vehicles to the set of vehicles it is receiving signals from via the in vehicle DSRC. Any vehicle without a transponder is then selected to have its license plate photographed. When the vehicle clears the second laser beam plane, a camera to photograph the license plate is triggered. This photograph is then electronically processed with OCR to identify and bill the owner. The computer system breaks down the license plate photographs into three categories—high confidence, low confidence or OCR unreadable. If a read is in the first category, it is then sent directly to the billing computers, which on the 407 ETR are referred to as the Revenue Management Service or RMS. The second two categories are manually processed by humans to identify the license plate number and then sent to the RMS for billing. About 80 percent of the license plate images are OCR high confidence meaning that only 20 percent of the non-transponder users of the 407 ETR require any direct human labor in the tolling process. In June 1998, about 67 percent of weekday traffic had transponders meaning that about 93 percent of all traffic was identified and billed only by computers—representing a significant labor savings to the operators of the ETR.

The interworkings of the Raytheon free flow tolling system

In order to defray the higher infrastructure costs associated with reading license plates, there is an additional $3.30 fee charged to all light vehicles using the 407 without a transponder. Transponders are mandatory for all vehicles weighing more than 5000 kilograms. Additionally, any light vehicle passing through the system with unreadable license plates is subject to a $50.00 toll per trip. This same $50.00 fee also applies to all heavy vehicles using the 407 without a transponder. There is a variable pricing plan on the 407, with tolls increasing by .85 cents per kilometer for light vehicles, 1.7 cents per kilometer for heavy vehicles, and 2.55 cents for multiple trailer heavy vehicles. If a multiple trailer vehicle were to travel the entire 108 km of the 407, the driver would save about $2.75 by not traveling with peak tolls.

Cross-Israel Highway

A second Raytheon system, operated by the Canadian Highways Infrastructure Corporation, the same company that operates the 407 ETR in Toronto, is being constructed in Israel. This tollway, referred to as the Cross-Israel Highway, Highway 6, or the Yitzhak Rabin Highway, is built on much the same technology as the 407 ETR. However, rather than have a closed tolling system, with tolls at every entrance and exit, Highway 6 has tolling gantries on the main road. This system requires significantly less infrastructure costs, but operates in exactly the same manner as the 407. Unlike the 407, Highway 6 will not directly bill vehicles without transponders. Rather, it is necessary for a vehicle without a transponder to purchase a day or trip pass. This will register the license plate with the system. Any vehicle that is not registered and also does not have a transponder is considered a violator, and the system automatically relays the license plate number...
downstream to an enforcement officer that can collect the toll and a fine.

**Switzerland Heavy Vehicle Fee**

Many researchers are turning towards GPS systems as a means of modernizing toll systems. Switzerland has implemented a tolling system that uses GPS receivers. In Switzerland, a Heavy Vehicle Fee (HFV) was instituted on January 1st of 2001. The fee is designed in order to force the operators of heavy trucks, which do the most damage to the roadways and the environment, to be forced to more accurately pay for the societal cost of their actions. The HFV is assessed to all vehicles that have a maximum fully loaded weight of more than 3.5 metric tons [about 7700 pounds]. The specific trip fees are calculated based upon the total kilometers traveled on all Swiss roads, the maximum weight of the vehicle, and the amount of pollution that the vehicle emits.

Each vehicle is assessed a fee for each mile that it travels, regardless of road type. In order to record the number of miles traveled, each Swiss heavy vehicle is required to install an On Board Unit or OBU. The OBU records the distance a vehicle has traveled via a tachograph’s direct cable connection to the tachometer of the heavy vehicle. The cable connection prevents user fraud. Additionally, the OBU contains a DSRC receiver, similar to those found in other tolling systems around the world. In addition to relaying information about vehicle miles traveled for billing purposes, the DSRC activates and deactivates the OBU at Swiss border crossings. Finally, the OBU contains a GPS receiver, which serves as a double check of the tachometer reading and whether or not the vehicle is inside of Switzerland. In order for the operator to interact with the OBU, it has a fairly simple keyboard and monitor. The keyboard and monitor make use of symbols to ensure that the OBU can be used by people who speak various languages. The OBU costs about $750 US, and is optional for all non-Swiss vehicles.

**New Highway Financing Opportunities in the US?**

In terms of new tolling applications, a system based on the Swiss model, when all HVs are assessed a per mile charge no matter what type of road they use, has potential for further development. For example, in the United States a gas tax is used in order to pay for the maintenance of roads. However, because of increasing fuel economies, less gasoline is needed for the same number of miles traveled, decreasing revenues. Additionally, the gas tax does not account for weight and pollution to the extent that the Swiss system does. The per mile traveled system, referred to as DAREA or Distance Dependent Area Pricing, could serve as an alternative to the gas tax system of collecting toll revenues. This system could be based on GPS technology, meaning that there would not need to be any infrastructure improvements in order for the system to work. Furthermore, by dividing vehicles into several classes, a DAREA system internalizes the external costs in terms of additional wear and pollution that are created by HVs.

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