# *International Case: Road Pricing Policy and Electronic Toll Collection (ETC) in Taiwan Freeway*


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Introduction to Author:
Eugene Chao is pursuing a Master degree at University of Pennsylvania concentrating in Infrastructure and Transportation. In Summer 2015, he worked for HNTB Corporation at Project Delivery Group. The previous year, he served for U.S. Federal Agency- General Services Administration. He received his Bachelor's in Business Administration with a major of transportation management.



Abstract

Road pricing policy on freeway and toll collection process have huge impacts to travelers' behavior. Author Eugene Chao reviews Taiwanese road pricing policy in the past 60 years and analyzes electronic toll collection systems' operational process, system application benefits and obstacles. At the end, he points out the opportunities of electronic toll collection in Information Communication Technology (ICT) industry (Figure1. Research Structure).

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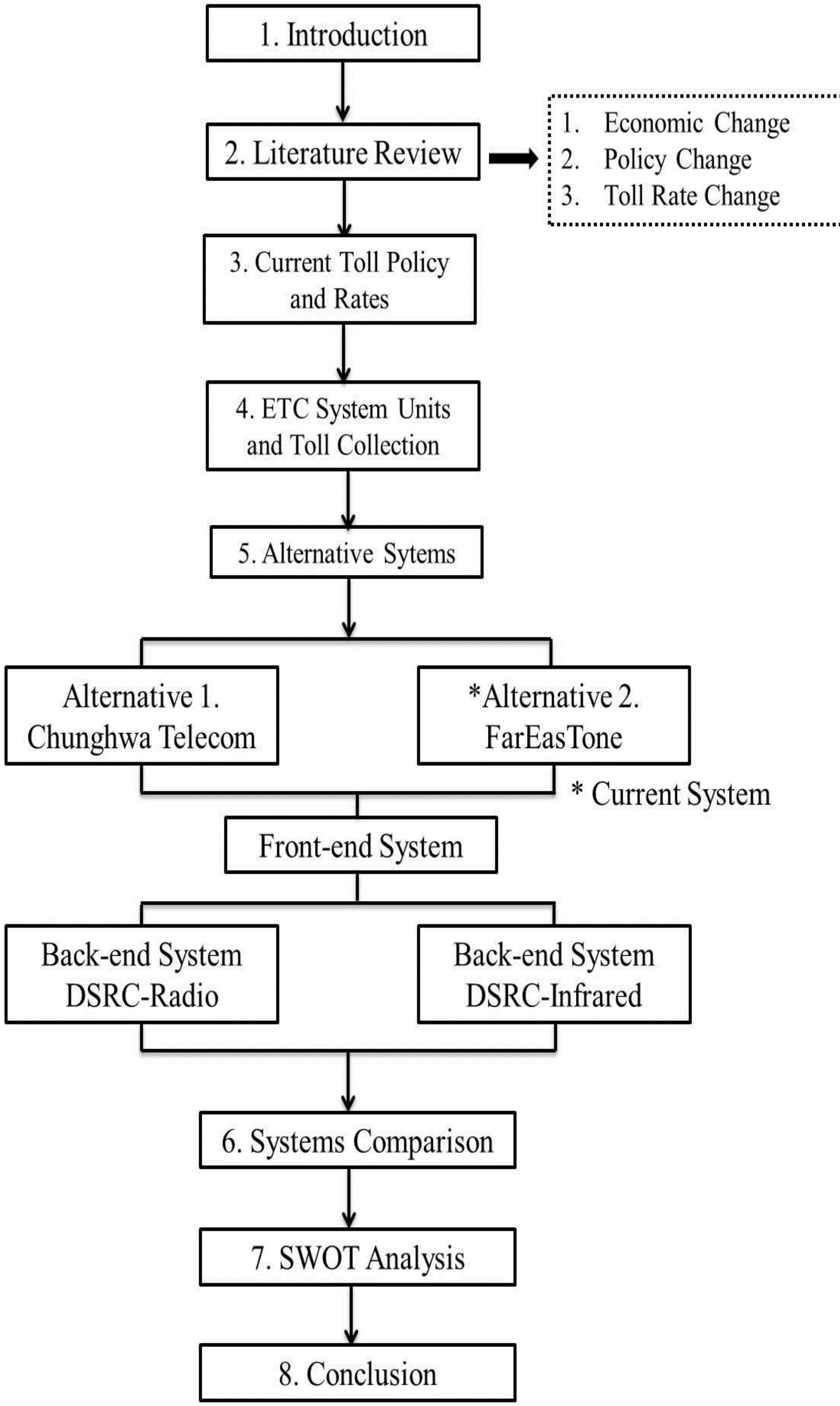
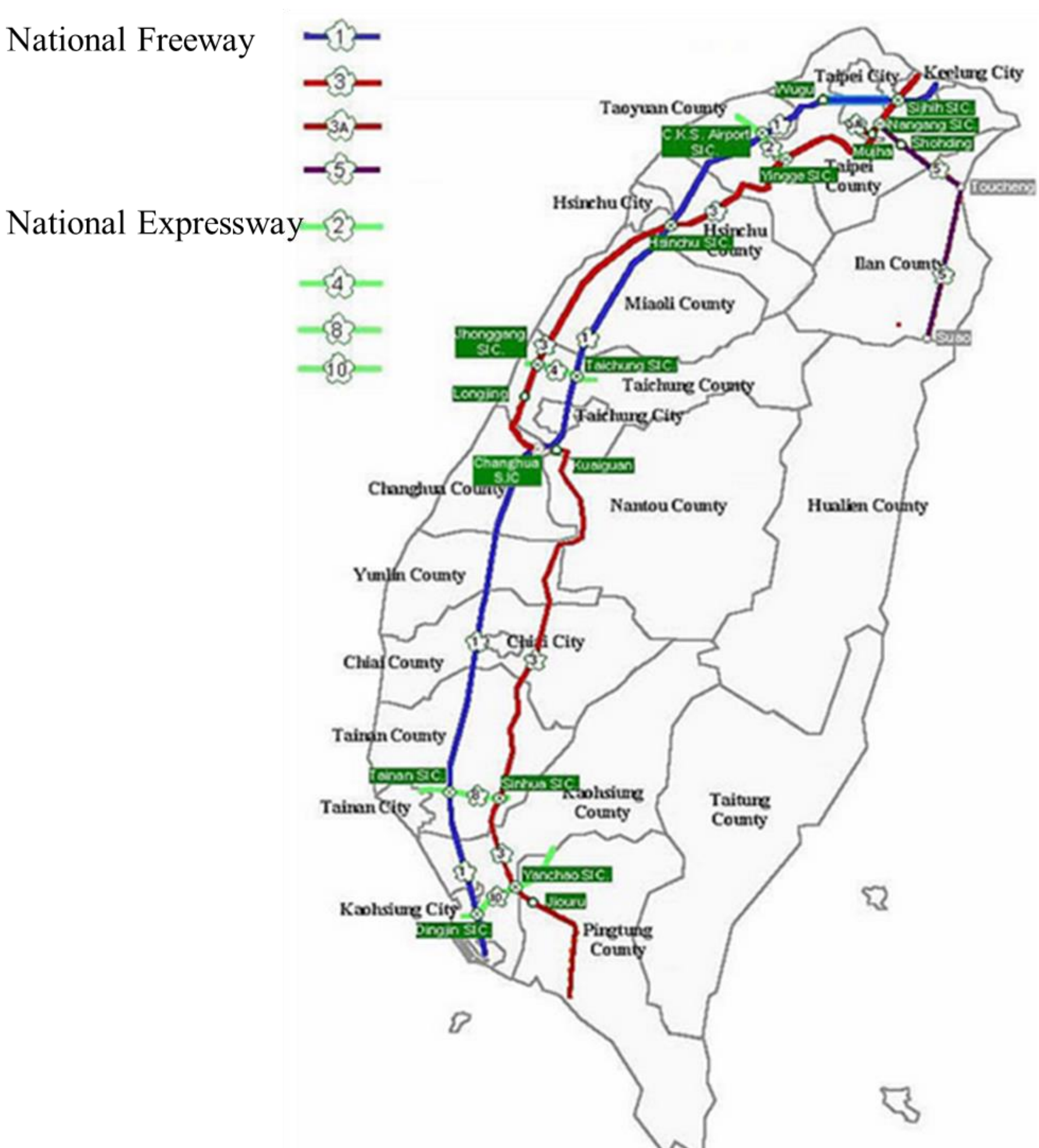
**Figure 1. Research Strcuture**



## 1. Introduction

On January 1st, 2014, the Taiwanese government enacted a "distanced-based" toll policy throughout the nation's freeway network. The toll rate is based on vehicle kilometer traveled (VKT) (Kuo, 2010), which requires drivers to pay a toll based on travel distance on freeways. Taiwanese freeway network is about 430 kilometers long (Figure 2).

Figure 2: Taiwan Freeway and Expressway Network Map




Source: MOTC, 2014; CECI-Taiwan, 2014

The toll policy should generate adequate revenue for long-term sustainability and be administered with fairness and efficiency (IBTTA, 2014). In terms of fairness, different types of vehicles should be charged at different rates. Furthermore, MOTC promoted several incentives to motivate drivers to use Electronic Toll Collection (ETC) lanes on freeways. For example, no matter which types of car are driven on the freeway, drivers travel less than 20 kilometer per day, it is toll-free. The shift in road pricing to VKT charging has made the already popular ETC system even more widely used by drivers.

## 2. Literature Review

Between 1960 and 1980, Taiwan was under a promising development due to the "Ten Infrastructure Projects", which is similar with the U.S. New Deal. Taiwanese President Chiang-Ching, Kuo; premier of the Executive office Yun-Suan, Sun ; secretary-general of the Executive office Shao Hwa, Chiu ; minister of economic affair Kwoh-Ting, Li, and authorities minister' officers contributed most of their effort to enact the ten infrastructure projects (MOTC, 2003). The projects include harbors, airports, freeways, railways, and energy. In 1964, Taiwan Area National Freeway Bureau, MOTC, delegated DeLeuw, Cather & Company to calculate toll rate based on arterial barrier version and ramp closure version. Considering freeway financial self-liquidating and economic effectiveness, MOTC decided to use arterial barrier version. At that time, the toll was based on a "flat rate". The toll for passenger cars, SUVs, and tractor trailers was $0.50, $0.75, and $1.00 respectively (Lai, 2006).

In 1971, with the increasing expenditure for freeway operation and maintenance as well as the decreasing revenue following the inflation, freeway ridership and system performance significantly declined. Therefore, MOTC decided to adjust toll price in order to reflect the real cost and raised the tolls for passenger cars, SUVs, and tractor trailers to $0.85, $1.00, $1.30 respectively (Lai, 2006).

In 1981, Taiwanese infrastructure project was in a transitional stage. A lot of extensive infrastructure projects happened, such as railroad and freeway extensive network project. In light of this, freeway trust fund needed to increase capital to bolster the expenditure of extensive projects. After a few capital increase meetings with authorities and voting, Legislative office finally agreed to increase the toll. For passenger cars, SUVs, and tractor trailers was $1.30, $1.75, $2.30 respectively (Lai, 2006).

Between May 9, 1949 and July 15, 1987, Taiwan underwent a strong regulatory period because the declaration of martial law controlled the freedom of media and citizens' civil rights. Anchors, columnists, reporters and media workers were not allow to publicly oppose government's policy or opinions. Citizens have been forbidden to travel to the Republic of China. Media industry and travel industry were the most regulated industries during this period (MOTC, 2003).

Moving forward, between 1981 and 1990, Taiwan economic system was transformed from a semi-capital to a liberal economic system. With the lifting of the martial law, the Taiwanese political atmosphere, media, and authorities, as well as citizens embraced an unprecedented open-mind to most public policy issues. The most important change before and after the martial law was citizen and media obtained more freedom to get involved in policy making process. Authorities were more willing to communicate and listen to citizen opinions and enhanced administrative efficiency. In response, many government organizations and institutions reformed their organization and abandoned bureaucracy to improve administrative efficiency and transparency. Taiwanese government had referenced multiple international cases about how to effectively refill the entire economy engine. Taiwanese government highly encouraged consortiums to get involved in infrastructure projects mainly through public private partnerships (P3). For example, the Continental Development Corporation got involved in freeway network project; China Engineering Consultants, Inc. got involved in sewage projects and so on. In addition, to enhance the vitality of government authorities, government-owned businesses transforming into privatization was the biggest trend during that stage. However, privatization is not always an ideal solution to boost official efficiency. One reason is once the government sold government-owned businesses, government would lose the sources that can raise its revenue (MOTC, 2003).

As cases accumulated, the government realized Build-Operate-Transfer (BOT) might be one of the alternatives to deliver infrastructure projects and access private capital as well as benefit the society. Essentially, BOT is an approach that government outsources infrastructure projects to private sector. At the beginning of BOT process, government invites engineering consulting firms, who may be interested in delivering service to bid on projects. The bid winner will start actions once contract has been signed. The action includes preliminary studies, design idea, project implementation, construction, and operation of the facility. Ultimately, after a specified concession period (usually 35 or 50 years), the ownership will transfer to the government (Menheere.S, Pollalis.S, 1996). The recent public projects in Taiwan have been operated by means of BOT. For example, the Continental Development Corporation, Taishin International

Bank, Fubon Commercial Bank Co., Ltd, Evergreen Group, Pacific Electric Wire & Cable Co., Ltd, TECO Electric and Machinery Co., Ltd. established Taiwan High Speed Rail Corporation to build HSR. In addition, ETC project was one of the largest BOT projects in the Taiwanese transportation history. Thanks to the technology, ETC system not only offered a convenient way for freeway drivers, but also increased traffic speed on freeway. The total of ETC usage rate at the first month (January, 2014) was 43 million (MOTC, 2014). Furthermore, the biggest change was the toll structure from a "flat rate" to the "VKT rate" (Kuo, 2010). That is, the toll was proportionally increase along with travel distance.

### 3. Current Toll Rates and Policy

The existing toll rate (Figure 3) in Taiwan is based on travel distance. Different types of vehicles are charged by different rate. Without any government funding and financial resource, FasEasTone successfully delivered a fully automated distance-based electronic tolling system. Actually, this toll pricing project was based on Build-Operate-Transfer (BOT), also known as a Public-Private-Partnership (PPP) (W. Lee, Wang & C. Lee, 2011).

Figure 3: Freeway Toll Adjustment by Distinguished Year

| Date | | Vehicles | SUVs | Truck Trailers |
|---|---|---|---|---|
| | | | Flat Rate | |
| *Jul 30, 1964* | NTD | 15 | 20 | 30 |
| *Jul 26, 1971* | | 25 | 30 | 40 |
| *Sep 1, 1981* | | 40 | 50 | 65 |
| *Jan 1, 2014* | | | VKT Rate | |
| Less than 20 kilometer/day | | | Free | |
| 20-200 kilometer/day | NTD | 1.2 | 1.5 | 1.8 |
| More than 200 kilometer/day | | 0.9 | 1.12 | 1.35 |

Soruce:: MOTC, 2014
Currency Exchange: 1 USD= 30.0 NTD
I mile = 1.609 kilometer

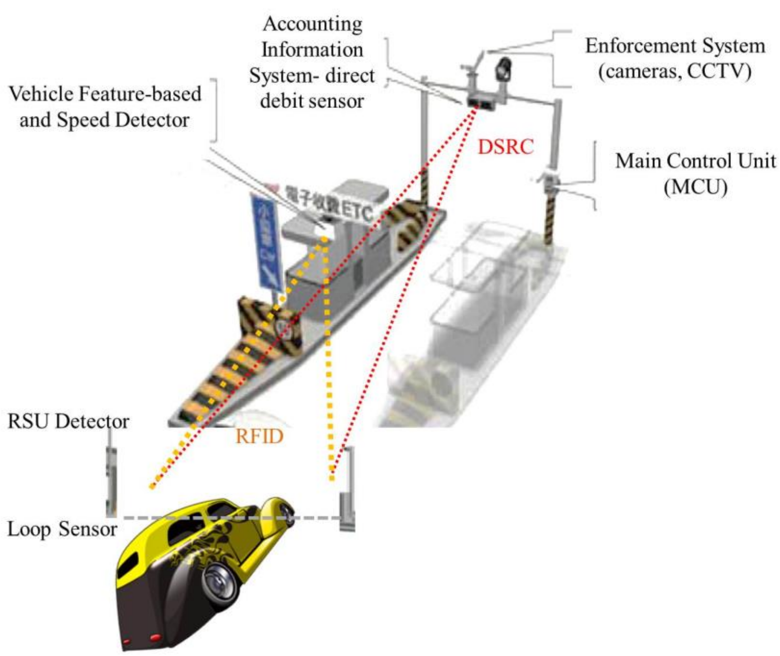
The total of ETC usage rate at the first month (January, 2014) was 43 million (MOTC, 2014), and the number increased 3.7 % compared to January 2013. Due to the growing usage number, the Ministry of Transportation and Communications (MOTC) has introduced peak and off-peak pricing policy (POPP) during the Chinese New Year. By means of POPP, the traffic flow has been evenly distributed throughout the Chinese New Year Period. Taiwanese POPP was based on region, period, and travel distance. In order to promote ETC system and advocate distance-based road pricing policy, MOTC designed several incentive programs. For example, if drivers travel with eTag (a small sensor attached to window), FarEasTone offer 10% discount on fees (MOTC, 2013).

## 4. ETC system units and Toll Collection Process

4.1 System units

Electronic Toll Collection (ETC) system includes six components: (1) eTag, (2) road side unit (RSU), (3) vehicle feature-based and speed detector- radio-frequency identification (RFID), (4) enforcement system - dedicated short-range communication (DSRC), (5) accounting information system - direct debit sensor, (6) main control unit (MCU) (Figure 4) (W. Lee, Wang & C. Lee, 2011).

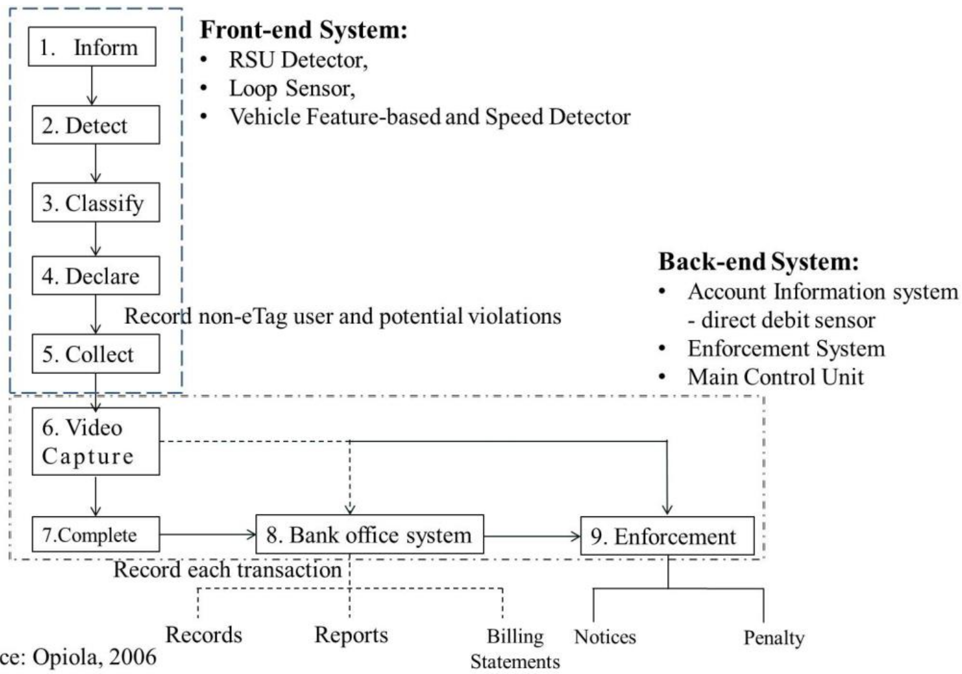
Figure 4: ETC System Units



4.2 Toll collection process

Road side detectors and loop sensors are installed underneath charging zone. These two units are called road side unit (RSU). RSU is to distinguish vehicle sizes and feature because larger vehicles have to pay higher toll (MOTC, 2013). Once a vehicle enters into the charging zone, eTag (a small sensor attached on window) will automatically be aroused by the RSU and start to identify vehicle's feature, size, and speed. The successful rate of vehicle identification mainly relies on the front-end RFID system (Figure 5).

Figure 5: Toll Collection Process




Source: Opiola, 2006

When a vehicle is driven through a gantry, the direct debit sensor will simultaneously check the eTag license, vehicular plate license, and the license holder's bank account information whether the information taken from the license and the bank are uniform. This procedure depends on back-end dedicated short-range communication (DSRC) system. DSRC is a communication layer between fixed roadside units and eTag using wireless access in vehicular environments. The direct debit system uses infrared rays during data transmission process. The suggested speed for a vehicle with eTag passing through the charging zone is lower than 120 kilometer/hr. Otherwise, the transaction process may fail. If the transaction process were to fail, the enforcement system contains cameras and Closed Circuit Television (CCTV), which capture the image of the unsuccessful payment vehicle (W. Lee, Wang & C. Lee, 2011).

In summary, ETC system uses multiple cameras, sensors, and control servers to identify, capture, and record vehicular data. Once the vehicle passes through a gantry, the direct debit system will simultaneously charge the toll and make the transaction. The average vehicle passes through gantries by using DSRC system is 10% faster (per hour) than the infrared system (Taiwan National Policy Foundation, 2006).

## 5. Alternative systems

After introducing ETC system and toll collection process, the following two ETC systems were proposed by two major telecommunication corporations. One is Chunghwa Telecom Co., Ltd; another is FarEasTone Co., Ltd (MOTC, 2008). These two telecommunication corporations proposed the same front-end system. However, the back-end system is different (Yu, 2004). This section will introduce the front-end and the back-end systems.

### 5.1 Front-end system

The front-end system includes eTag, loop sensors, road side unit (RSU) detector, digital video recorders (DVRs), vehicle feature-based and speed detector. The way each unit communicates with others heavily relies on RFID. The Taiwanese ETC technology is based on Ultra-High Frequency (UHF) RFID. The communication is through radio wireless electric wave and the frequency is between 860 and 960 MHz. The system components can be generalized as two categories: eTag and Reader (Yu, 2004). The eTag stores driver and vehicle information, such as drivers' driving history, travel behavior, and vehicle kilometer traveled. Within the hundred meters distance range, the Reader is able to read the information stored on the eTag. Through mutual communication the Reader can verify driver's identification and vehicle's information.

#### 5.1.1 eTag

The eTag (Figure 6) can be divided into two communication types: active communication (also named as propagation coupling), passive communication (inductive coupling). The size of active communication device is about one coin and the data can be stored in the eTag. The size of data memory is at least 1MB. The maximum communication distance is 100 meters. Once an eTag has been attached to a vehicle, the vehicle is able to transmit signal to the Reader. The signal transmission relies on mutual recognition. However, one active eTag concern is the device maybe overheated due to the inner temperature and outside weather. For passive eTag, one advantage is the eTag can obtain signals and save transmission energy from the Reader that directly solves the power problem. Most importantly, the passive device unlike the active one needs battery. Consequently, the passive eTag is relatively durable, cheaper, and lighter; however, transmit distance is shorter than activate device transmit distance.

Figure 6: Front-end System- eTag


Source: FarEastTone, 2013

5.1.2 Reader

The Reader (Figure 7) relies on Ultra-High Frequency (UHF) to transmit signal and the speed of verification is at least 50 units per second. The entire UHF-RFID includes three components: antenna/loop, transceiver and transponder. The Reader combines the functions of transceiver, decoder, and antenna. The Reader is also named as interrogator. The active etag includes transponder (transmitter+responder) plus antenna. The passive etag includes transponder plus loop. Generally, there is no major difference between Reader and Interrogator, but in telecommunication filed, Interrogator is a combination of Reader, decoder, and interface (Yu, 2004).

Figure 7: Front-end System- Reader


Source: MOTC, 2013

**5.2 Back-end system**

The back-end system includes an enforcement system - dedicated short-range communication (DSRC), an accounting information system - direct debit sensor, and a main control unit (MCU) system (W. Lee, Wang & C. Lee, 2011). There are two ways to let units communicate with each other: DSRC-Microwave and DSRC- Infrared. DSRC is a wireless technology which activates safety, mobility, and environmental applications for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) (U.S DOT- RITA, 2014). In 1999, the U.S. Federal Communication Commission (FCC) allocated 75MHz of spectrum at 5.9GHz to be used exclusively for V2V and V2I communication in the U.S (Alto, 2004). In the case of Taiwan, ETC back-end system is proposed by two telecommunication companies: Chunghwa and FarEasTone. Chunghwa company proposed DSRC-Microwave as its back-end system. FarEasTone company proposed DSRC- Infrared system. These two back-end systems have pros and cons. MOTC ran through a bidding process and selected FarEasTone company as Taiwanese ETC system provider and operator (MOTC, 2008).

The decision considers which ETC technology system is relatively mature, two telecommunication companies business operation proposal, eTag after-sales service, telecommunication companies public relation, and concession years.

5.2.1 DSRC-Microwave

The DSRC-Microwave system includes three major components: on board unit transponder (eTag), road side transceiver (Reader), and transceiver antenna. Sometimes, road side transceiver and transceiver antenna may combine into a single unit, called beacon (CIT, 2006).

5.2.2 DSRC- Infrared

A typical DSRC- Infrared system is named as the Infrared Beacon, which is composed by an infrared transceiver, a beacon head and a beacon controller (CIT, 2006).

## 6. Systems Comparison

The comparison will focuses on the front-end system under different circumstances, such as window components and vehicle speed. In addition, this section will discuss the advantages and disadvantages of the microwave system and the infrared system. Lastly, the DSRC back-end system contrast table (Figure 8) will show which telecommunication's technology demonstrates greater advantages than the other.

Figure 8: DSRC Back-end System Technology Comparison

| Telecom Company | Chunghwa | FarEacTone |
|---|---|---|
| Plan | A | B |
| Proposed Back-end system | Microwave | Infrared |
| Unit of Frquency | 5.8GHz | 922MHz |
| Region | Freeway | Artery |
| Transmission Speed | 4Mbps | 1Mbps |
| Transmission Range (Diameter:miles) | 12.4 | 2.17 |
| Data Transmission Frequency per transciever | 2~3 | 2~3 |
| Data Received Frequency | 25Kbytes | 10Kbytes |
| Information Provide Distance: miles | 620 | 20 |
| Inforation Transmision Volumn: texts | 25,000 | 10,000 |

Source: MOTC ETC Open Bid Report

### 6.1 Comparison of Front-end system

***Vehicle window components.*** Transmitting signal might be affected by vehicle window components. If the window components contain higher proportion of metal, the eTag may have difficulty to transmit signals due to impunity (Yu, 2004).

***Diagonal of vehicle window.*** Sensitivity rate of the Reader would be affected by the diagonal of vehicle window or head light, which indirectly cause the failure of vehicle feature-based recognition (Yu, 2004).

***Vehicle Speed.*** Successful vehicle verification rate depends on speed. If a vehicle speed is over 120 kilometer/hr, the Reader does not have enough time to identify vehicle size (Yu, 2004).

***Bandwidth and Transmission speed.*** Transmission speed plays a decisive role during the data exchange process. Bandwidth also affects transmission speed. If the bandwidth is not enough, data may not able to transmit successfully (Yu, 2004).

***Distance and Electric power.*** Reader's electric power, eTag sensitivity rate, antenna orientation, and distance between the eTag and Reader have a strong association with the data transmission. If the Reader is installed in an open area, without any intervention, the decrease of electric power of the Reader is inversely proportional to the square of distance. If the Reader is installed in an inner area, the reflection will generate multiple paths and the decrease of Reader's power is inversely proportional to the fourth power of distance (Yu, 2004).

***Positioning transponder***. The positioning transponder applies RFID technology to ETC. Transponder is installed on the pavement. Once vehicles pass through the ETC lane, the transponder will automatically communicate with the eTag and verify vehicular information (Yu, 2004).

## 6.2 Comparison of Back-end system

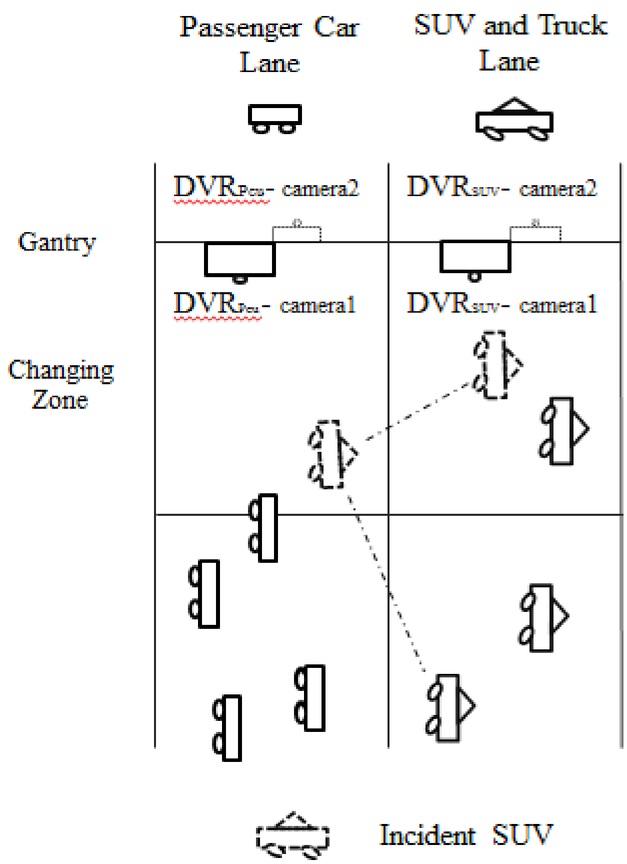
***DSRC-Microwave***

The DSRC-Microwave has several advantages. First of all, the Microwave system is one of the mature technologies in RFID industries. Singapore (ERP), Japan (ETC), H.K (Auto toll), U.S. (E-Z Pass), Canada (Highway407), Norway (Auto pass), and Australia (MCL) are using microwave as their back-end system (CIT, 2006). Based on MOTC report - the discussion of the Taiwanese freeway ETC technology and policy, ETC- DSRC Microwave market share is about 95% worldwide (Chang, 2012). Second, due to the widespread use of the microwave system, there are plenty of system providers and operators around the world. They are able to share the experience and know-how once the partnership is developed. In addition, the Microwave system components are well coordinated and compatible. Finally, the responsibility of system producers and platform providers are clear cut, they are able to produce devices massively.

However, using the DSRC-Microwave as the ETC back-end system has several disadvantages. First, electronic wireless may be affected by surroundings. For example, if a slope is over 20 degrees or in a mountainous area, the road side transceiver may receive plenty of wireless signals from transponder because of physical diffraction and interference. Second, the transceiver antenna cannot penetrate metal surfaces; therefore, the transponder and the transceiver are usually installed outside of vehicles. From an aesthetic perspective, it is visually attractive to see exposed devices. Furthermore, the transceiver antenna exists blind side. Transceiver antenna may have difficulty detecting vehicle features at several angles. Accordingly, before establishing antenna, engineers have to spend time to testify in order to find the best location. This may increase overhead cost of the project. A final disadvantage is that the mismatch record between the enforcement system and DVR-camera system may potentially cause payment problems for the driver.

The following scenarios demonstrate how payment problems could happen. For instance, most microwave systems can only be used for single lane to detect vehicle feature and collect toll. If a SUV mistakenly enters passenger car lane, rather than SUV lane, the driver immediately realizes it and quickly shifts to the SUV lane. The DSRC-Microwave system may not able to charge the right toll based on vehicular size. Then, the driver would face two situations. One is that the system regards SUV as a passenger car and the system charged SUV as a passenger car toll rates, rather than SUV toll rates at first. The driver needs to pay an extra toll for the remaining difference. Another situation is even though the enforcement system successfully distinguish vehicle feature as a SUV and charged it correctly. However, the $DVR_{Pcu}$- camera1 record SUV as a passenger car, but $DVR_{Pcu}$- camera2 had no record, instead the SUV visual record shown on $DVR_{SUV}$-camera1 and $DVR_{SUV}$- camera 2 (Figure 9). This inconsistency creates an inconvenience for drivers. To solve this pricing and image mismatch, the driver needs to provide eTag identification code and driver's ID as well as historical records to MOTC-Bureau of Freeway.

Figure 9: Mismatch Record in Waving Traffic Scenario



***DSRC- Infrared***

One advantage of using DSRC-Infrared as back-end system rather than using DSRC-Microwave is because the frequency is higher. In some situations, the DSRC-Infrared is able to detect vehicle feature while vehicle speed is high. However, the MOTC suggested that drivers should keep the speed under 200 kilometer/hr in order to make sure the transceiver has enough time to receive signals. Another strength is the bandwidth. The bandwidth is able to tweak in order to fit the surroundings. For instance, in a mountainous area, the transmission signals between the transponder and the transceiver may not be well connected; thus, engineers need to adjust the bandwidth to solve the transmission signals' problem. The wider the bandwidth the better connection it will be. The other benefit is the system's flexibility. In some cases, drivers may enter a wrong ETC lane, such as a SUV entering a vehicle lane. Therefore, waving is unavoidable. Even in high frequent waving situations, the infrared system is still able to detect right vehicle's feature, collect right toll, make transactions, and record driving.

The advantages of infrared system: (1) able to deal with dynamic traffic flow in multiple lanes, (2) does not need protocol permission and channel license, (3) less physical diffraction or interference (4) save engineers angel detecting works for figuring out where is the ideal site for transponder and transceiver (Yu, 2004). In terms of signal transmission, the transmission successful rate of DSRC- Infrared is higher than DSRC-Microwave; therefore, the operational and maintenance cost is cheaper.

Although FarEasTone technicians and engineers advocated the advantages of Infrared system, Professor Chang doubts its commonality. One of his arguments is that Infrared system is only 5% of market share, while FarEasTone proposed a low market share system. Operating and maintenance cost is relatively higher. Even worse, if the system cannot operate as expected, Taiwanese government may have to step in and take over the system, which directly increase cost and erodes the freeway trust fund. On the other hand, Taiwan is known for its famous original design manufacturer (ODM) and original equipment manufacturer (OEM) microwave component providers. It is doubtful that MOTC chose a system made by another country (Chang, 2012). Another weakness of infrared system is the toll booths. As aforementioned, infrared system can deal with free flow at multiple lanes, however it only happens if there are no toll booths between ETC lanes. Regarding a toll booth as a barrier, the transponder may fail to transmit signals to transceiver because of the possibility of diffraction or interference (Yu, 2006). In light of this, MOTC decided to demolish all the toll booths to ensure the transmission is successful (MOTC, 2014). The deconstruct cost of the toll booths should be evaluated. The other weakness is the transmission quality during inclement weather. For example, during a heavy rain, the vehicle plate recognition function may be inaccurate due to the moisture, dusts, and smog (Yu, 2006).

## 7. Strengths, Weaknesses, Opportunities, Threats

### *7.1 Strengths*

**Efficient use of transport system.** Enacting road pricing and the ETC system to expedite traffic flow on freeways allow vehicles move more efficient. Traffic signals, stops signs, wayfindings, and other technology devices increase vehicular mobility as well as reduce queue length and delay.

**Congestion Alleviation.** Effectively managing traffic flow and vehicle movement ensures vehicular efficiency. In order to eliminate congestion, the MOTC asked the Taiwanese Legislative office to demolish all the tollbooths on freeways (MOTC, 2014).

**Emissions Reduction.** ITS and other innovative forms of traffic management, ETC and road pricing, could reduce vehicle travel time, improved traffic flow, decreased idling, and other efficiency of operations, which result in lower energy use and GHG emissions. Common GHG emissions include carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), ozone, water vapor, carbon monoxide (CO), oxides of nitrogen ($NO_x$), hydrocarbons (HC) and volatile organic compounds (VOC) and chlorofluorocarbons (DOT, 2010).

**Revenue Generation.** Charging freeway users, based on the distance and vehicular types, will compensate the Taiwanese freeway trust fund. Furthermore, enacting discrimination on peak and off-peak policy (DPPOP) during specific interval would generate extra revenues for the fund. The existing charging mechanism considers financial sustainability self-liquidation (MOTC, 2013).

**Increased Safety.** Speed limitation on several zones ensures drivers stay compliant with regulations. For example, MOTC enforced a safety law that all the drivers should drive their vehicles under 200 kilometer per hour when passing through the gantry. In addition, at some easily congested areas and interactions, the maximum speed is 72 kilometer per hour (MOTC, 2014). Police officers enforce drinking test at certain important entrances.

**Convenience and Comfort.** Installing toll tag kiosks on every convenience and popular retail stores provides an user-friendly way for eTag users who need to purchase or refill their accounts (Ely et al., 2013). Moreover, the FarEasTone mobile apps offer eTag users easily check their payments and account balance (FarEasTone, 2014). The MOTC official website provides real-time freeway information, which allows drivers to plan their routes in advance. These three incentives provide a more efficient way to use Taiwanese freeway system (MOTC, 2014).

*7.2 Opportunities*

**Vehicle-to-Infrastructure (V2I) Communication.** ETC system is an approach to let vehicles communicate with infrastructure. Connecting vehicle to a back-end infrastructure to retrieve information from the vehicle or to allow vehicle to access network resources will alleviate congestion and delay (Ely et al., 2013).

**Vehicle-to-Vehicle (V2V) Communication.** Connecting vehicles to each other allows them to share and exchange information that enacts vehicles to diagnose surroundings and traffic movement to ensure safety. In a traffic accident scenario, vehicle can send out a warning message to the following vehicle, avoiding massive collision and queuing. In a traffic jam scenario, the broken-down autonomous vehicle will turn on their hazard warning lights, communicating congestion information back to other vehicles (Ely et al., 2013). The transmitted signals are through DSRC (dedicated short range communications) (Alto, 2004).

**Portable devices-to-Vehicle (P2V) Communication.** Connecting portable devices to vehicle allows drivers to enhance the vehicle's functionality (Ely et al., 2013), like telematics. Audio entertainment includes movies and music, which creates a leisure atmosphere for passengers during travel. Online navigation system could be downloaded into mobile device to provide reliable trip plan and alternative routes if necessary. Mobile apps will provide restaurant, tourism, parking information for users.

**Interoperability.** To integrated V2I, V2V, and P2V communication together, it will solidify the function of ITS. Cloud computing and blue genes will give an optimal answer to users based on the self-learning experience database (IBM, 2014). If the ITS-Cloud were to work, then the following single vehicle applications could be available to customers at almost no extra cost: infrastructure-based warning (traffic lights, traffic signs, curves, etc.), drive-through payments (gas station, parking, fast food, etc.), wireless diagnostics and flashing, electronic toll collection; digital entertainment, points of interest information, digital map updates, and traffic updates (Alto,2004).

*7.3 Weaknesses & Threats*

**Enforcement Issue.** One of the commonalities for the research papers is enforcement issue. One controversy is the in-car passenger detection camera because it could recognize people's face easily no matter brightness or darkness. The innovation of facial detection technology is able to correct light and remove reflection in order to accurately capture people's facial characteristics. Sometimes this technology plays a crucial role to assist police trace criminals. On the other hand, facial detection technology may violates people's privacy (MOTC, 2013). In 2000, Office of the Privacy Commissioner in Australia has published a guideline called " Personal privacy practices for the electronic tolling industry" which named as Australian Standard, defining the task of systems providers and authorities. In the guideline, it clearly defined the role. For example, one of the propositions indicated that the need to assign a unique identifier to individuals should be carefully considered by operators. ETC information should not be used for any purpose other than the operation of the ETC system, or sold or given to any other entity. In addition, customers should be encouraged to check and correct such information and data on a regular basis. Operators should be committed to openness and public scrutiny of managing users' private information and data (Ogden, 2001). In short, the MOTC and the FarEasTone suggest to give road and eTag users a clear explanation about how to exercise users' right (Liu, 2014).

**Risks of Build-Operate-Transfer (BOT).** A respondent described BOT as a good approach to let consortiums get involved in big government projects. However, there are three important aspects that government and consortiums need to deal with together. First of all, government should assist to promote and advertise the ETC system. Second, as time went by, traffic demand may increase due to the growth of population and any other factors. To deal with the potential demand, government may enact new policy. This new policy may have a conflict with the previous and the existing policy, which may lead to consortiums lose costumers, market share, and revenue. Therefore, government should make sure that a new policy not only should *never* conflict with the on-going policy but also *never* generate another problem. Third, the overoptimistic ridership projections may harm the ETC system because of unmet ridership and less publicity. Public awareness and willingness also play a decisive role for the success of BOT projects. In summary, BOT can be regarded as a method to encourage private sectors to invest in infrastructure projects, but it also could be considered as a potential threat to private entities because of uncertainty.

**Customer relation.** Customer relation and after-sale service are significant factors to business's success. In the case of the Taiwanese ETC system, the first and second version of mobile apps provided by FarEasTone is inconvenient because eTag users cannot check their accounts immediately whether the payment is success. The transaction record takes one to three days. In some cases, users received notice and penalty due to transaction failure. In the first month of operating period, there were about three hundred transaction failures (FarEasTone, 2014). During system adjustment period, people complained about the unstable system and uninstalled the eTag. The Taiwanese media reported this inconvenient system and intentionally raised public awareness in a bias and massive way. With failure cases accumulated and bias media report, FarEasTone President became irritate and delivered a few unpleasant remarks. Some eTag users organized a group called " Unhappy to install eTag" to against the ETC system and FarEasTone telecom company. The challenge here is to provide reliable ETC devices at a convenient way and ensure availability and excellent customer service and support to users.

**Fairness and Equity.** Some groups are hard to change their travel behavior, especially low income group (Kamarulazizi & Ismail, 2006). The MOTC and the FarEasTone failed to mention how to assist the low income group to deal with new policy and system. In addition, the MOTC demolished all the toll booths on freeway in order to enhance vehicular efficiency. The MOTC and the FarEasTone failed to give a clear answer to tell full-time and part-time toll collectors and staffs who used to work in toll booths where are their future jobs would be. Eighty percent of them have been laid off due to the strict job transfer threshold given by FarEasTone. For example, if a toll collector does not obtain a college degree, the toll collector may not be eligible to transfer. In FarEasTone Corporate Social Responsibility (CSR) official report 2012 version (the latest version), it did not mention any plan or policy about how to take care of toll collectors and staffs and why FarEasTone requires to set up a rigid threshold to those want to transfer. On March 9, 2014, about 750 toll collectors and staffs established a self-help organization. The same year, On April 22, the self-help organization members protested on the MOTC office (PTS News Network, 2014). Union protest is a hidden social cost need to be addressed in the contract.

## 8. Conclusion

The paper has reviewed the Taiwanese road pricing policy in the past 60 years and has demonstrated the advantages and disadvantages of the Taiwanese ETC systems. The current system is not the commonest system on global ETC market and still has points can be improve. However, the distanced-based toll policy and fully automated toll collection system provide a great efficiency improvement on Taiwanese freeway system. Looking forward, the opportunities of ETC, V2I - V2V - P2V - Interoperability, has high potential to generate billions, or even trillions of dollars in Information Communication Technology (ICT) not only in Taiwan, but also in the global market.

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