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Considering Better Highway ETC System: Comparison between Japan and Taiwan

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Abstract: This paper reviews the development and application of electronic toll collection (ETC) on highways. Japan's and Taiwan's development experiences of highway are provided and compared as case studies. Potential challenges and future development issues when implementing the highway ETC policies are highlighted. Finally, managerial strategies and policy implications are considered.

Keywords: Highway, electronic toll collection, Japan, Taiwan

1. INTRODUCTION

In recent years, rapid economic development and urbanization have accelerated the growth in numbers of highway passengers and the volume of freight traffic. In the past, drivers traveling near the ramp along the lane have often had to slow down to allow vehicles from the ramp to merge onto the highway. Also, recurrent (e.g. peak hours) and non-recurrent (e.g. accident) traffic jams have potentially reduced highway volume and affected vehicle travel efficiency, consequently bringing both potential environmental externalities and a loss of social resources. Today, however, these issues have been greatly ameliorated by many advanced traffic management strategies implemented on the basis of real-time traffic information collection and analysis, for example electronic toll collection (ETC) systems (Levinson and Chang, 2013; Tseng et al., 2014; Abuzwidah and Abdel-Aty, 2015; Wan et al., 2016). Past researchers have adopted various perspectives to investigate the issues related to ETC or highway, such as electronic vehicle charge (Yang et al., 2004), driving flow improvement (Klodzinski and AI-Deek, 2004; Hsu and Zhang, 2014), highway safety (Yang et al., 2014), road pricing (Iseki and Demisch, 2012), privacy (Riley, 2008), fuel consumption (Venigalla and Krimmer, 2006; Perez-Martinez et al., 2011), environment and external costs (Tseng et al., 2014; Hiasa et al., 2016). However, the actual development processes and experiences of ETC have seldom been studied in the past literatures. Therefore, the main purpose of this paper is to help fill this gap. Japanese and Taiwanese highways are chosen as cases and then their characteristics are compared. The contribution of this paper can provide the newest development and application information for highway ETC situation. Some policies suggestions are provided for decision makers in the highway authorities and other stakeholders. The paper is organized as follows. Section 2 presents the background of highway ETC systems. Then, case studies of Japan and Taiwan are presented in Section 3 and Section 4 discusses the differences between Japan and Taiwan. Finally, key issues and policy suggestions are provided in the concluding remarks section.

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2. THE BACKGROUND OF ELECTRONIC TOLL COLLECTION ON HIGHWAY

In the early stages of toll collections, highway tolls were collected manually (MTC) in most countries. Drivers had to stop their vehicles at the toll station and thus the vehicle speeds had to be reduced, with subsequent adverse effects on vehicle flow and also potential effects on externalities. Also, highway accidents had the increased possibility of occuring in the toll plazas due to the reason that drivers need to quickly and carefully stop and start their vehicles. In order to further improve travel efficiency, safety and potential external costs problem (e.g. CO_2 emissions)., electronic toll collection (ETC) systems have been extensively applied in many countries to replace traditional manual toll collection systems (e.g. Germany, Netherlands, US, Japan, Taiwan, and elsewhere) through the intelligent transportation system application and open road tolling infrastructures since the 1960s. Principally, ETC is composed of three components which are: in-vehicle devices, smart card (ETC card), and roadside equipment. It is argued that many factors must be considered when implementing ETC system, such as construction and maintenance costs, application system types, highway users' willingness to pay the toll charge fee, usage conveniences, driving behaviour, privacy, and other factors (Riley, 2008; Komada et al., 2009; Chen, 2009; Jou et al., 2011; Jou et al., 2013; Chiou et al., 2013; Kuo, 2015; o and Chen, 2016). Also, a variety of quite different stakeholders might be involved in ETC investment, construction, maintenance, and toll policies. For example, vehicles users, highway construction companies, transport consultant companies, highway toll operators, bank and credit card companies, highway authorities and security administration, vehicle dealers and equipment supply companies (Wang et al., 2011; Saad et al., 2018). Therefore, various stages of ETC implementation (including design, planning, construction, maintenance, etc.) commonly tend to require significant levels of negotiation and time to work through. Also, in recent years, the advanced information and communications technologies have significantly improved ETC operation performance (e.g. charge correction rate, vehicle identification and enforcement, etc.) and further integrated traffic data applications through approaches such as big data analysis, travel behavior analysis, travel time forecasting (Amorim et al., 2014)

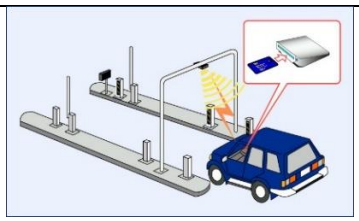
3. CASE STUDIES

3.1 Japanese Highways

In 1997, ETC was first started to conduct test operation in Japan. In 2001, ETC was formally introduced and started in all Japanese areas and the number of ETC users have gradually grown. According to official data provided by the Ministry of Land, Infrastructure, Transportation and Tourism[1], the ETC utilization rate reached over 50 % in 2005, and 90% by 2016. The ETC communication system used is the Dedicated Short Range Communications (DSRC) system, which enables the system to transmit communications within a solid and robust operational environment. All ETC users must insert an ETC card into the ETC in-vehicle device installed in the car and then the ETC system can record the travel data and charge the highway fare (see Figure 1). The ETC cards are issued by credit card companies. In Japan, ETC in-vehicle devices are sold by car dealerships or automobile supply stores. Drivers must input their car information in the device before using it. Currently, most highways have hybrid (combination of MTC and ETC) toll collection systems. Most drivers

[1] http://www.mlit.go.jp/road/yuryo/etc/riyou/index.html

use the ETC system and a few drivers who do not use ETC device still prefer to use cash to pay the highway toll.



ETC card


In-vehicle ETC unit


In-vehicle ETC 2.0 unit

Figure 1. ETC system in Japan
Source: https://www.hanshin-exp.co.jp/english/drive/first-time/etc.html
http://www.mitsubishielectric.com/bu/automotive/products/etc/index.html

In recent years, the in-vehicle ETC 2.0 Unit have started to be introduced in Japan. This updated version equipment can offer Global Positioning System (GPS) function and other comprehensive applications, such as a car navigation system that can receive wide-area road traffic information (e.g. congestion, accident), upcoming road information, integrative supportive information, big data application, and other features. Also, ETC 2.0 supports safe driving and avoids vehicle congestion in zones with information equipment which is called as "ITS spot"[2]. ITS spot provides traffic information and is set on almost all highways in Japan (Figure 2). Finally, it can offer a 20% highway toll discount granted for ETC 2.0 unit users in certain non-congested routes (e.g. Ken-O highway) in order to balance traffic flow.

Figure 2. ETC 2.0 System
Source: Ministry of Land, Infrastructure, Transportation and Tourism
http://www.mlit.go.jp/en/index.html

[2] http://www.mitsubishielectric.com/bu/automotive/products/etc/index.html

3.2 Taiwanese Highways

In Taiwan, the traditional manual toll collection (MTC) system was first introduced in July, 1974 and continued to be introduced until February, 2006 (Figure 3). In order to gradually attract drivers to adapt a new toll system and improve the efficiency and other potential external costs (e.g. emission, accidents, etc.), a hybrid (combination of MTC and ETC with DSRC based communication system) toll collection system was then conducted between February, 2006 to December, 2013 (Figure 4). Many drivers behaviour was widely researched in an attempt to increase ETC acceptance and reduce potential barriers (Jou et al., 2011; Jou et al., 2013). At this stage, driver users had to buy an on board unit (OBU) and then it could send a signal to a road side unit (RSU) in the ETC system. At this stage, there is no discounted toll rate for ETC user. However, such an extra cost burden was considered to hinder the adoption of ETC. Thus, in order to increase the utilization of ETC, on May 15, 2012, a free eTag was offered for highway users to replace tradition OBU equipment. Adopting eTag can offer 10% discount on highway tolls in order to promote the utilization of ETC. OBU users were entitled to receive free eTags in addition to receiving refunds for their OBUs and, following the introduction of this policy, ETC utilization has significantly increased. Finally, freeway toll fee application was switched from a frequency-based fixed rate to a more equitable distance-based toll collection system on 2 January, 2014 (Figure 5).

Figure 3. Manual toll collection system
Source: Taiwan Area National Freeway Bureau, Ministry of Transportation and Communications[3]

Figure 4. Hybrid (combination of MTC and ETC) toll collection system
Source: Taiwan Area National Freeway Bureau, Ministry of Transportation and Communications[4]

[3] https://transport-curation.nat.gov.tw/toll/detail/Publish1_3.html
[4] https://transport-curation.nat.gov.tw/toll/detail/Publish1_3.html

Multi-lane Free Flow Gantry

Windshield eTag

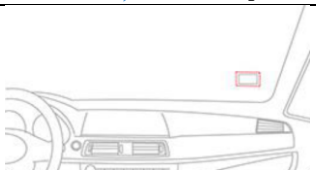
Figure 5. ETC system in Taiwan
Source: Taiwan Area National Freeway Bureau
http://www.freeway.gov.tw/english/Default.aspx

4. DISCUSSION OF ETC COMPARISON BETWEEN JAPAN AND TAIWAN

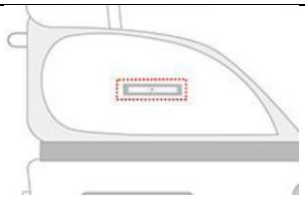
Japan and Taiwan have experienced various ETC implementation and adoption stages and these processes can be summarized into four research streams. First, highway ETC sensor facilities are different. In Japan, an ETC card must be inserted in the in-vehicle facility. In Taiwan, an eTag must be set on the headlamp or windshield of the car or somewhere in the car. These facilities can wirelessly connect with highway toll gates when drivers pass through them and in this way all trip data is recorded.

「ETC card」 in Japan

Information sharing through road side facilities



Windshield eTag in Taiwan



Headlamp eTag in Taiwan

Figure 6. ETC card in Japan and eTag in Taiwan
Source: https://www.fetc.net.tw
https://www.go-etc.jp/etc2/index.html

The second difference is with the highway operation and management units. ETC in Japan involves many operators and administrators (e.g. highway authorities, highway companies, credit card companies, ETC coordinator, etc.). Every main administration area has different highway companies (e.g. East Nippon Expressway Co., Ltd.[5], West Nippon Expressway Co., Ltd., etc.[6]), each with their own individual highway pricing and managerial strategies. Thus, highway operations and maintenance commonly require more time to be allocated to allow for effective communication and negotiations. In Taiwan, in contrast, the highway bureau has adopted public-private-partnership (PPP) approach to designate Far Eastern Electronic Toll Collection Co., Ltd. (FETC) to establish and operate the ETC system through granting a build-operate-transfer (BOT) concession right of 20 years. It is noted that

[5] https://www.e-nexco.co.jp/en/
[6] https://global.w-nexco.co.jp/en/

in Japan and Taiwan, “highway” and “expressway” are common used together in the official websites and company websites. In this paper, we use “highway” to replace “expressway” in order to make it consistent.

Third, although their calculation rules are both distance-based, the highway toll charge methods differ between Japan and Taiwan. In Japan, flexible road pricing is applied to certain areas (e.g. Tokyo and Osaka). Taking Tokyo-Osaka as an example, charge rate is 0.20 US$/km =21.8 yen/km. In Taiwan, however, travel is offered free of charge when the travel distance is less than 20 km. Then, in Taiwan, charges are US$ 0.04/km and US$ 0.03/km when the travel distance is between 20~200 km and over 200 km, respectively. From the user pay principle (Pigou, 1920), it is suggested that Taiwan’s highway authorities could consider cancelling the free of charge policy even the travel distance is less than 20 km due to the fact that some people still travel only short-distance (less than 20 km). It is believed that such a principle can help alleviate the congestion problems (and related external costs) and increase travel speed on the highways (especially in peak hours), since part of travel flow would shift to other alternative routes.

Finally, regarding potential issues or challenges, in Japan, the Japanese government has started to introduce ETC 2.0 to replace the traditional ETC system. This might well need some time to deal with system transformation and cost burden. Also, most Japanese ETC systems consists of a hybrid (combination of MTC and ETC) system of lanes. This means drivers can still use cash to pay the toll fare should they prefer to do so. Arguably though, the highway authorities must think how to encourage these cash pay highway users to adopt ETC card and then achieve a complete ETC system driving environment in the future.

In Taiwan, two main challenges still exist regarding ETC implementation and development. The first is that previous toll operators who worked in MTC stations have still struggled to obtain reasonable compensation since their jobs were replaced by ETC. Also, the equitability of the charge fair is another issue since freeway drivers are charged as they use the freeway No. 1, No. 3, No. 3A and No. 5. However, freeway No. 2, No. 4, No 6, No. 8 and No. 10 are free due to the policy consideration.[7] Table 1 shows the ETC main comparisons between Japan and Taiwan.

Table 1. ETC comparison between Japan and Taiwan

	Japan	Taiwan
Launch year	2001	2006
Highway	High density highways are located in Tokyo, Osaka, Sapporo, Sendai, Nagoya, Kyoto, Fukuoka, Hiroshima, etc.	1. Highway No.1 2. Highway No.3, No. 3A 3. Highway No.5
ETC card	ETC card 	eTag 
Utilization rate of ETC card	1. Year 2018 (91.2%) 2. Year 2017 (90.3%) 3. Year 2016 (89.6%) 4. Year 2015 (87.9%) 5. Year 2014 (85.6%)	1. Year 2018 (93.5%) 2. Year 2017 (90.3%) 3. Year 2016 (93.6%) 4. Year 2015 (93.0%) 5. Year 2014 (93.5%)

Source: http://www.mlit.go.jp/en/index.html
http://www.freeway.gov.tw/english/Default.aspx

[7] https://www.freeway.gov.tw/english/Default.aspx

Table 1. ETC comparison between Japan and Taiwan (cont.)

	Japan	Taiwan
Operation mode	1. Ministry of Land, Infrastructure, Transport and Tourism takes charge the operation of highway. 2. A credit card company issues ETC card and charge toll. 3. An equipment manufacturer makes the ETC device and car shops sell and install them. 4. An ETC facility maker maintains the ETC gate. 5. ITS Technology Enhancement Association is the coordinator	1. Far Eastern Electronic Toll Collection Co. (FETC) operates the ETC system and charge toll through the contract of Build, Operate, Transfer Operator (BOT) 2. Freeway Bureau (Ministry of Transportation and Communications) supervise the ETC operator
Toll charge method	Drivers are charged based on distance travelled via ETC card/cash. Vehicle types include small, standard, mid-size, large-size, over-size vehicle.	1. Drivers are charged based on distance travelled via eTag. 2. Vehicle types include compact car, bus, truck.
Charge rate (take compact car as an example)	Charge rates are flexible based on time of day (e.g. peak and non-peak hour) and areas. Taking Tokyo-Osaka as an example, charge rate is 0.20 US$/km =21.8yen/km (=12,000yen/550 km) Assuming 1 yen = 0.009 US$	1. Free of charge when travel distances is less than 20 km 2. US$ 0.04/km when the travel distance is between 20~200 km 3. US$ 0.03/km for distances of over 200 km 4. Driver can enjoy 25% toll fare discount when travel distance is more than 200 km within one day.
Potential challenges	1. The transformation of in-vehicle ETC unit to in-vehicle ETC 2.0 2. How to conduct all ETC systems	1. How to resolve the situation of previous toll operators. 2. Fair charge for all highway users

Source: http://www.mlit.go.jp/en/index.html
http://www.freeway.gov.tw/english/Default.aspx

5. CONCLUDING REMARKS

Efficient highway pricing and management mechanisms can effectively achieve a safe and convenient driving environment. An ETC system can improve highway operation performance (e.g. driving time wastage, accidents, fuel and emission reduction and unnecessary quarrels, etc.) and has been widely adopted in many countries since the 1960s. Using Japan and Taiwan as case studies, this paper has reviewed their development experiences, current applications and future potential challenges. It is clear that, in general,

ETC development experiences three stages: firstly a traditional manual toll system, secondly a hybrid (combination of MTC and ETC) toll system, and finally an all ETC system. Toll charging methods have changed from a frequency-based fixed rate to a distance-based toll collection system and can help achieve a more economically equitable road pricing environment. Flexible pricing mechanism can be implemented in order to balance traffic flow during peak and non-peak hours, such as on the Ken-O highway in Tokyo metropolitan area. Nevertheless, although an ETC system can provide many technical and operational benefits (e.g. safety, big data analysis, etc.), some potential issues should be remembered, and effective solutions to resolve these negative impacts considered. These are issues such as the work rights of previous toll operators, the cost burden of system transformation (e.g. from ETC to ETC 2.0 unit in Japan), and other issues. Also, other countries' ETC systems can further be researched and compared in future study through both quantitative and qualitative analyses. It is hoped that the research findings of this paper can help inform other countries' future considerations for more effective highway ETC systems and service quality and help solve potential problems for highway authorities, system operators, highway users and other stakeholders.

REFERENCES

Abuzwidah, M., Abdel-Aty, M. (2015) Safety assessment of the conversion of toll plazas to all-electronic toll collection system. *Accident Analysis and Prevention*, 80, 153-161.

Amorim, M., Lobo, A., Rodrigues, C., Couto, A. (2014) Optimal location of electronic toll gantries: The case of a Portuguese freeway. *Procedia - Social and Behavioral Sciences*, 111, 880-889.

Chen, H.C. (2009) Policy change in Taiwan's freeway electronic toll collection system: An integrative analysis model. *Political Science Review*, 39, 1-53.

Chiou, Y.C., Jou, R.C., Kao, C.Y., Fu, C. (2013) The adoption behaviours of freeway electronic toll collection: A latent class modelling approach. *Transportation Research Part E*, 49, 266-280.

Dias, J., Matos, J.N., Oliveira, A.S.R. (2014) The change collector system. *Procedia Technology*, 17, 130-137.

Hiasa, S., Noori, M., Kelly, C., Tatari, O. (2016). Dynamic techno-ecological modeling of highway systems: a case study of the Shin-Meishin Expressway in Japan. *Journal of Cleaner Production*, 115, 101-121.

Hsu, W.T., Zhang, H. (2014) The fundamental law of highway congestion revisited: Evidence from national expressways in Japan. *Journal of Urban Economics*, 81, 65-76.

Iseki, H., Demisch, A. (2012) Examining the linkages between electronic roadway tolling technologies and road pricing policy objective. *Research in Transportation Economics*, 36, 121-132.

Jou, R.C., Chiou, Y.C., Ke, J.C. (2011) Impacts of impression changes on freeway driver intention to adopt electronic toll collection service. *Transportation Research Part C*, 19, 945-956.

Jou, R.C., Chiou, Y.C., Kuo, C.W., Tan, H.I. (2013) Freeway drivers' willingness to pay for an on board unit under an electronic toll collection system. *Transportation Research Part C*, 27, 16-24.

Klodzinski, J., AI-Deek, H.M. (2004) Evaluation of toll plaza performance after addition

of express toll lanes at mainline toll plaza. *Transportation Research Record*, 1867, 107-115.
Komada, K., Masukura, S., Nagatani, T. (2009) Traffic flow on a toll highway with electronic and traditional tollgates. *Physica A*, 388, 4979-4990.
Kuo, Y.W. (2015). Analyzing drivers' adoption intentions of eTag service of electronic toll collection system on the freeways. *Journal of the Chinese Institute of Transportation*, 44(3), 215-242 (in Chinese).
Levinson, D., Chang, E. (2013) A model for optimizing electronic toll collection systems. *Transportation Research Part A:Policy and Practice*, 37, 293-314.
Perez-Martinez, P.J., Ming, D., Dell'Asin, G., Monzon, A. (2011) Evaluation of the influence of toll systems on energy consumption and CO2 emissions: a case study of a Spanish highway. *Journal of King Saud University-Science*, 23, 301-310.
Pigou, A.C. (1920) Wealth and Welfare, Macmillan, London.
Riley, P.F. (2008) The tolls of privacy: an underestimated roadblock for electronic toll collection usage. *Computer Law & Security Report*, 24, 521-528.
Saad, M., Abdel-Aty, M., Lee, J. (2018) Analysis of driving behavior at expressway toll plazas. *Transportation Research Part F*, in Press. https://doi.org/10.1016/j.trf.2017.12.008
Tao, C.C., Chen, T.K. (2016). Sentiment orientation analysis of Internet public opinions by using social computing-The case of implementing distance-based electronic toll collection policy on Taiwan's freeway. *Journal of the Chinese Institute of Transportation*, 28(3), 295-334 (in Chinese).
Tseng, P.H., Lin, D.Y., Chien, S. (2014) Investigating the impact of highway electronic toll collection to the external cost: the case study in Taiwan. *Technological Forecasting & Social Change*, 86, 265-272.
Venigalla, M., Krimmer, M. (2006) Impact of electronic toll collection and electronic screening on heavy-duty vehicle emissions. *Transportation Research Record*, 1987, 11-20.
Yang, S.N., Cheng, W.S., Hsu, Y.C., Gan, C.H., Lin, Y.B. (2004) Charge scheduling of electric vehicles in highways. *Mathematical and Computer Modelling*, 57. 2873-2882.
Yang, H., Ozbay, K., Bartin, B., Ozturk, O. (2014) Assessing the Safety Effects of Removing Highway Mainline Barrier Toll Plazas. *Journal of Transportation Engineering*, 04014038, 1-7. Doi: 10.1061/(ASCE)TE.1943-5436.0000681
Wan, K., Nguyen, N., Alagar, V. (2016) Dependable traffic control strategies for urban and freeway networks. *Mobile Networks and Applications*, 21, 98-126.
Wang, J.Y.T., Lindsey, R., Yang, H. (2011) Nonlinear pricing on private roads with congestion and toll collection costs. *Transportation Research Part B*, 45, 9-40.