Chapter 70
Allocation Criteria for Increasing Electronic Toll Collection Gates on Freeways Determined Using Simulation Analysis

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ABSTRACT

In Taiwan, the electronic toll collection (ETC) system for freeway toll plazas that commenced operation in February 2006 will operate on all freeways by 2014. When the ETC system was first implemented, each toll plaza was allocated 1 small-vehicle ETC gate and 1 large-vehicle ETC gate. Determining how to allot the gates to ETC and manual toll collection when the number of ETC vehicles increases is crucial. By conducting a simulation using the toll plaza simulation model, the authors observed that 1 ETC gate for passenger cars had to be added to the small toll plaza when the traffic exceeded 1,450 vehicles/hr/gate. The medium and large toll plazas required 1 more ETC gate for passenger cars when the traffic exceeded 1,600 vehicles/hr/gate, whereas 1 non-ETC gate for passenger cars could be removed.

INTRODUCTION

The application of electronic toll collection (ETC) system contains interdisciplinary technologies such as telecommunications, image processing techniques, and radio frequency identification techniques. Toll stations in Taiwan are located on freeway mainlines and are used to collect traditional multi-trip tickets or cash tolls. This type of toll station has been used in many countries, but often causes traffic jams, and its hardware facilities and operation are costly. Therefore, an

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ETC system has been implemented to increase the capacity of toll stations, shorten toll collection time, and enhance the safety and convenience of road use. Furthermore, ETC system is conducive to reducing energy consumption and pollution. European and North American countries have adopted an open-road tolling system (Samuel, 2009; Smyth, 2009; Jai, 2009), and Taiwan also plans to adopt an open-road tolling system.

In Taiwan, the ETC system commenced operation on February 10, 2006 and will be applied to all freeways by 2014. Each toll station was initially equipped with one ETC gate for small vehicles and one ETC gate for large vehicles. Because the number of vehicles using ETC gates has increased, two or three ETC gates for small vehicles have been established at several toll stations; nevertheless, manual toll collection gates continue to be phased out and the number of ETC gates continues to increase. In response to the increase in the vehicle flow rate on freeways and the number of vehicles using ETC, determining the rate at which the number of ETC gates for small vehicles should be increased and how to allocate manual toll collection gates is a crucial objective.

According to the plan of the National Freeway Bureau (NFB) developed in 2003, ETC gates for small vehicles must gradually be increased from left to right based on the growth of traffic passing through ETC gates. The number of gates must be increased when ETC gate traffic approaches service capacity, that is, (a) when the flow rate of the ETC gate for small vehicles is 1,600 vehicles/hr/gate in 2 consecutive hours on 2 consecutive days; (b) when the weekly average peak flow rate of the ETC gate for small vehicles is higher than 1,200 vehicles/hr/gate; or (c) when the average flow rate of the ETC gate is higher than 16% of the total traffic capacity of the toll station on 5 consecutive days or on 15 days in 1 month. However, these numbers are rough, and the effect of adding one ETC gate for small vehicles on the overall service level of the toll station should be evaluated. Adding ETC gates affects the total flow rate and usage rate of ETC as well as the allocation of other gates. Therefore, the purpose of this study was to identify the criteria for allocating toll gates on freeways in response to increased ETC use.

Because of the complexity of toll station operation, which is influenced by a variation in flow rate with time, vehicle composition, toll collection mode, and number of toll gates, we used the second version of the toll plaza simulation (TPS) model provided in Chapter 8 of the 2011 *Highway Capacity Manual* (2011 Taiwan HCM; Institute of Transportation, IOT, 2011) by the Taiwan IOT to simulate various scenarios. Based on the simulation results, we used total vehicle flow rate and ETC small vehicle usage rate as variables to reflect toll station operating and service performance, and identified the criteria for allocating ETC gates at toll stations of various sizes. The results can serve as a reference for NFB policy and management.

The parameters of the simulation conducted in this study are listed as follows:

- One large, one medium, and one small toll station were selected.
- Total traffic flow and ETC small vehicle usage rate were used as the control variables.
- The influence of weigh stations on toll station operation and traffic flow was ignored.
- The number of ETC gates for small vehicles was increased from the inside lane to the outside lane.
- Gate operation could not be reversed.
- A mixed ticket and cash gate for large and small vehicles was not considered.

TOLL STATIONS IN TAIWAN

Toll Collection Types and Toll Gate Allocation

Freeway toll gates in Taiwan are divided into the following five types: (a) exclusive ETC gates for