Hi-PASS, THE VERY GREEN SOLUTION IN KOREAN EXPRESSWAYS

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ABSTRACT

Around a toll plaza, Vehicles do such maneuvers as slow down, stop, and speed up to pay their tolls when they use ordinary toll gates. They can be expected more fuel consumptions compared to the vehicles which use the Hi-pass, a Korean type of Electronic Toll Collection System (ETCS). To measure the exact amount of difference between the two gas consumptions, we equipped a test vehicle with a measurement system and installed a model toll gate on our test field. Through the field tests on fuel consumptions, we could confirm a 36.7 % of energy saving when the test car used the Hi-pass. Then we projected the result on the total traffic volumes which had used national expressway network for five months from January 2009. Projected to the whole traffic, potential cost savings reached 5.34 billion won. We expect frequent quotations of this result to prove the fuel efficiency of the Hi-pass system.

Key-words: ETCS, Hi-pass, Fuel Consumption, Test Vehicle, Field Test

1. INTRODUCTION

Recently, “Green Growth” is making the conversation issue in the world. Major advanced countries are focused on issues, such as efficient and environment-friendly use of resources; Korea also suggested its new national vision, ‘Green Growth,’ which based on ‘Green Industry’ and ‘Green Technology.’

ETCS (ETCS, Electronic Toll Collection System), one of the most importance projects of ITS, a representative of green growth in the transport sector is an advanced green system ensuring fuel savings and CO_2 emission through non-stop toll collection.

In implementing ETCS, Korea Highway Corporation developed and operates “Hi-pass,” an automatic fare collection system based on DSRC. Hi-pass is proliferated to the entire expressway since December 2007 through pilot run over a period of time; of the daily traffic usage, 42.3% is using Hi-pass lanes as of February 2010 and the number of devices distributed amounts to 366,000 units.

The study mainly focuses on revealing fuel efficiency among many other effects, which can be obtained through Hi-pass use, such as convenience, time benefit, fuel savings, and CO_2 reduction. In general, when a vehicle passes through a toll gate, it reduces driving speed (approach a toll gate) → stop (pay a toll) → increases speed again (merge with main lane), and at this point, additional fuel will be used due to acceleration and deceleration. Hence, the study attempts to quantitatively verify the fuel consumption efficiency of Hi-pass by comparing fuel consumptions of general vehicles, which would operate as aforementioned driving and vehicles using Hi-pass that pass through toll gates without stopping, although the driving speed is slower than driving in mane lanes due to safety reasons.

Besides the time savings and convenience an individual would feel in using Hi-pass, there is a limitation to experience fuel savings at firsthand due to the short toll gate passing time in addition to the absence of mechanism. We believe however, the fuel consumption reduction that combined the entire expressway in national-level will be very effective.

For fuel consumption measurement, we implemented a data acquisition system on a test vehicle and chose to operate the vehicle experimentally according to pre-set conditions. The study also estimated fuel reduction effect that occurred on expressways, targeting vehicles using actual expressways based on experimental results.

The study results may be used as based materials henceforth in increasing the use of Hi-pass, as the amount of fuel savings will be suggested in a quantitative value according to Hi-pass use; also it can be used to analyze the positive effects of Hi-pass in the environment-protection perspective, and resource savings through Hi-pass.

2. EXPERIMENT PLANNING

2.1. Status of Hi-Pass

To improve toll gate jamming due to the continuous increase of expressway traffic, Korea Highway Corporation conversed some parts of manual toll collection systems operated by manpower into Hi-pass, an electronic toll collection system, using OBU (On-Board Unit). As shown in Figure 1, Hi-pass-only facilities are installed to ensure vehicles to pass through in certain speed without stopping to pay a toll.

Figure 1 – Hi-Pass Lane at Toll gate

Since expansion installation of Hi-pass in expressways nationwide, there was a rapid increase in utilization as people experienced time savings at toll gate and convenience.

Judging from the ratio of Hi-pass use and device distribution based on February 2010, the utilization is 42.3%, which is an increase by 30.3% compared to 2009 in the same month and 124.6% compared to 2008 in the same month. The increased utilization is about 1.25 times in just two short years, which is a surprising figure.

In addition, the number of devices distributed in February 2010 reaches 366,000 units, an increase of 303.6% compared to 77.5% in February 2008 and 2009. As such, we can see that the device distribution has also increased rapidly in alongside with the fast increase of utilization.

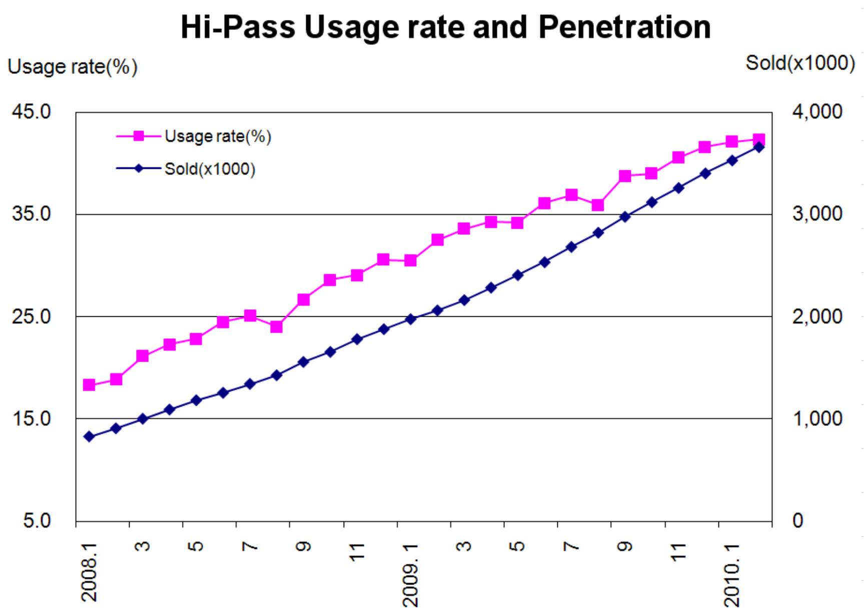

Figure 2 - Current Status of Hi-Pass

2.2. Basic Assumption

The fuel consumption differences between vehicles using Hi-pass lanes at toll gates and general lanes may be shown as Figure 3.

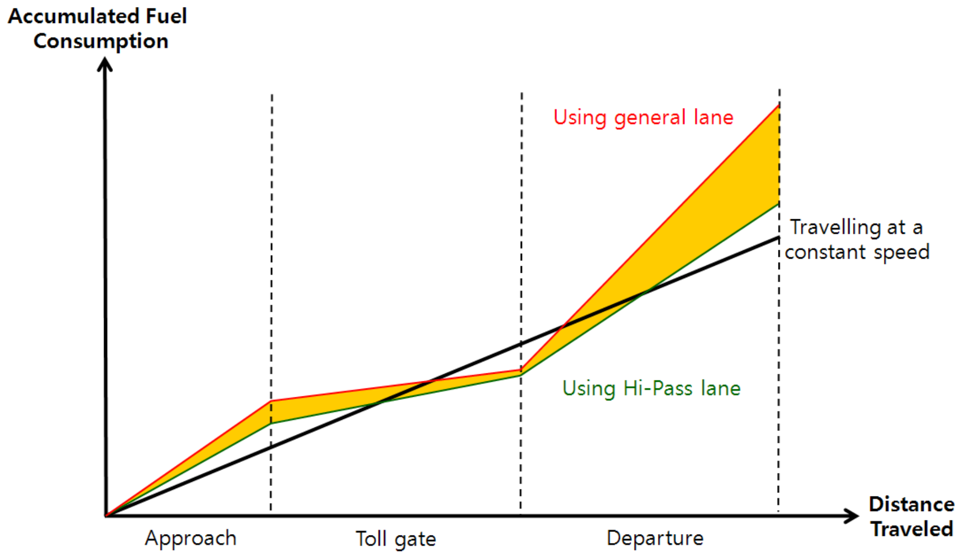

Figure 3 - Fuel consumptions comparison by toll gate passage pattern

First, in “general driving,” the cumulative fuel consumption increases at constant rate according to travel distance. Vehicles using “Hi-pass lanes” reduce speed to approach a toll gate and maintain constant speed at a toll gate section and accelerate again to merge into main lanes. The acceleration and deceleration behavior will slightly increase fuel consumptions than that of "ordinary driving."

"General lanes" require rapid acceleration and deceleration than "Hi-pass lanes," resulting relatively higher fuel consumptions as idle time is added – to pay a toll fee - spanning 6 to 14 seconds.

As such, we can see that vehicles using general lanes at toll gates have higher fuel consumptions than that of using Hi-pass lanes as rapid acceleration is required to reach driving speed and rapid deceleration. In relation to travel distance conceptually, the difference in fuel consumptions between bilateral in the specific point is relevant to the height of the shaded area marked in Figure 3.

2.3. Experimental Methodology

To quantitatively estimate the fuel consumptions according to the driving behaviors presumed in the previous paragraph, the study planned and implemented the following experiment.

2.3.1 Experimental Condition

To compare the use of "Hi-pass" and "general lane" as explained above, we configured three types of experiments as follows:

Experiment 1: Using Hi-pass lanes,
- While driving in 60km/h, a test vehicle reduces the speed to 30km/h near a toll gate, and accelerates again after paying a toll to merge with main lanes.

Experiment 2: Passing through an entry toll gate using general lanes,
- While driving at 60km/h, a test vehicle stops at a toll gate, spends about 6 seconds for ticketing, and accelerates to merge with main lanes.

Experiment 3: Passing through an exit toll gate using general lanes,
- While driving at 60km/h, a test vehicle stops at a toll gate, spends about 12 seconds for the paying process, and accelerates to merge with main lanes.

2.3.2 Experimental Section

Toll gates installed in actual roads are different in their type and operating methods, thus it is impossible to select environmental condition for standardization. Therefore, the study selected the experimental section considering safety issues, such as stopping sight distance according to speed of test vehicles.

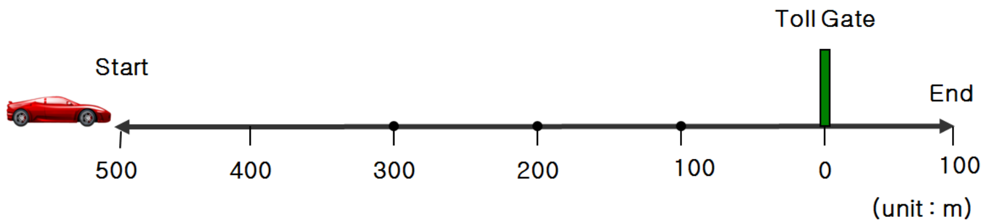

Figure 4 - Experimental Section

The actual driving test was taken place at the test track of Korea Transportation Safety Authority and experiments with a copy of expressway closed-section. That is, the study selected a total of 600m as an experimental section; 500m point to upper direction and 100m point to lower direction based on a simulation toll gate.

2.3.3 Test Vehicle

To measure fuel consumptions using Hi-pass lanes and general lanes, the study used a sports utility vehicle (SUV), which is a first-class vehicle in terms of operating system.

The load conditions for a test vehicle are; empty vehicle weight, one driver, and 2,095kg with experimental equipment loaded, and tire pressure condition is adjusted according to manufacturer-recommended air pressure (30psi).

A non-contact optical speed sensor was used to precisely measure the vehicle's driving speed from outside; through this, the driver can check and control initial driving speed at the test section, which is 60km/h, 30km/h, when entering into a Hi-pass lane, and 0km/h speed when stopped using a general lane.

Inside the vehicle, to check fuel consumptions, the study installed a data measurement device and a monitor for driver confirmation that process and stores data, such as diesel fuel flow meter, power supply, and speed and fuel flow.

Figure 5 - Test Vehicle

2.3.4 Experiment Procedure

Using the test vehicle aforementioned, the study implemented experiments in the following methods:

a. The test vehicle drove at 60km/h, 500m ahead of the specified toll gate. In other words, the driver began measuring fuel consumptions and checked speed from 500m point on every experiment implementation in the same experiment condition.

b. The test vehicle droved at 60km/h using a general lane and stopped at a toll gate. The stop is configured to 6 seconds in the entry of closed-tollgate in an expressway and 14 seconds in the exit. The stopping time we used in the experiment is based on survey and experimental results executed by Korea Highway Corporation.

c. In the case of Hi-pass lanes, the test vehicle drove at 60km/h, reducing the speed to 30km/h in a tollgate section (50m section each; before and after a tollgate), and recover its original speed.

d. The study confirmed and compared the fuel consumed during 600m driving on each vehicle using general and Hi-pass lanes.

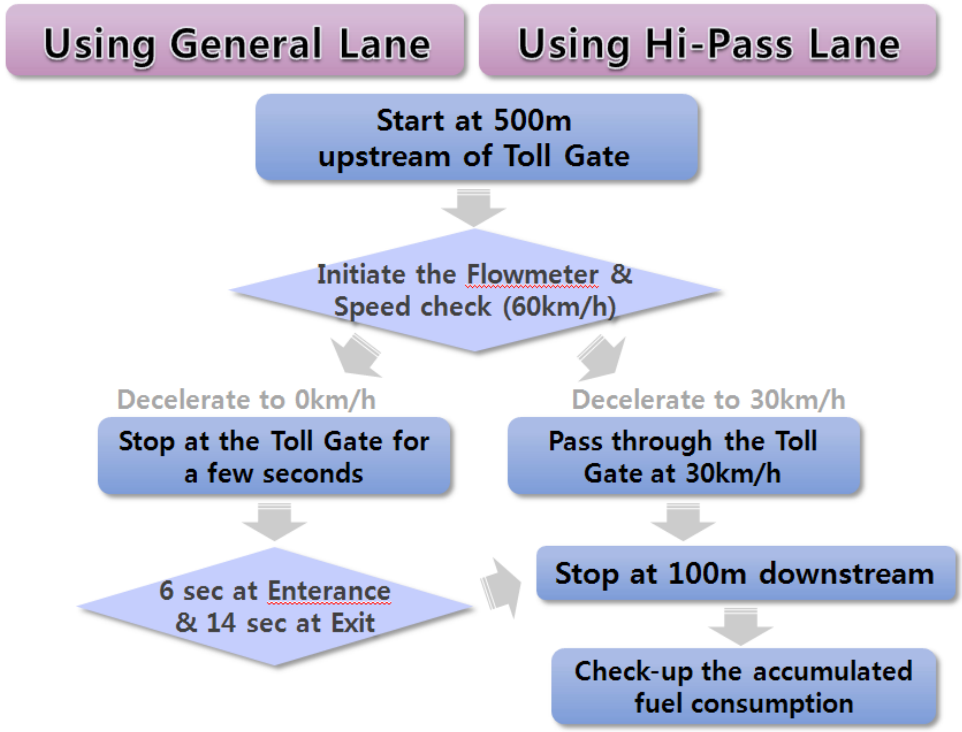

Figure 6 - Experimental Plan

3. EXPERIMENTAL RESULTS AND THE EFFECT OF HI-PASS

3.1. Experimental Results

Figure 7 illustrates experimental results of each condition over three times. As a result of actual experiment implementation aforementioned, the experiment 3 (exit to toll gate by general lanes) shows higher fuel consumptions than that of experiment 2 (entry to toll gate by general lanes), while the experiment 1 (Hi-pass lane use) demonstrates the least fuel consumptions.

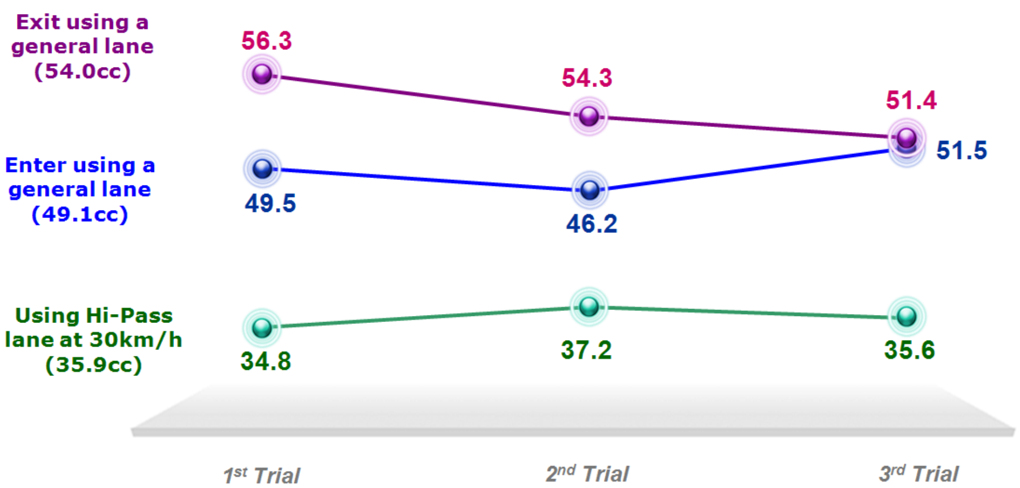

Figure 7 - Fuel Consumptions Comparison according to Experimental Results

Through Table 1, we can learn that the experiment 2 has more fuel consumptions than the experiment 1 by 13.2cc (a 36.7% increase). Moreover, the experiment 3 consumes more fuel than the experiment 1 by 18.1cc (a 50.4% increase). Despite the relatively short experimental section, vehicles use relatively much more fuel due to idling according to acceleration and deceleration as well as fare collection.

Table 1 - Experimental Results

Classification	Fuel Consumptions (cc)	Fuel Increase Compared to the Experiment 1 (cc)
Experiment 1 (Hi-pass Lane)	35.9	-
Experiment 2 (When approached a toll gate through general lanes)	49.1	13.2
Experiment 3 (Exit a toll gate using general lanes)	54.0	18.1

In addition, in a case where a vehicle driving in a closed-section uses a toll gate through general lanes, it will use a total of 103.1 cc fuel, such as 49.1 cc at the time of entry and 54cc on exit, while a vehicle using a toll gate through Hi-pass lanes consumes a total of 71.8cc fuel, only 35.9cc fuel regardless of entry-exit. Hence, fuel consumptions can be reduced up to 31.3cc using Hi-pass lanes compared to general lane use. Suppose oil price is 1,500 won per ℓ and examined the cost efficiency of fuel consumptions, we can see that a vehicle passes through a toll gate via an Hi-pass lane saves about 47 won fuel cost in a round-trip travel.

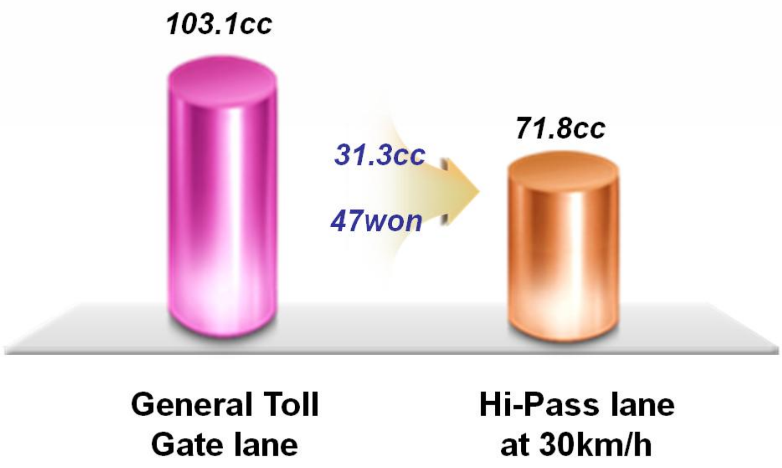

Figure 8 - Fuel Saving Effect

3.2. Fuel Saving Effect with Hi-Pass

The study aims to analyze fuel saving effects according to Hi-pass use targeting first-class vehicles (about 85% of total vehicles) via expressway toll gates from January to May 2009 using the aforementioned experimental results. Figure 9 shows the analysis procedure of fuel saving effects.

According to the analysis procedure above, the results demonstrating fuel reduction effects developed from entire expressway network considering expressway traffic volume and the estimation of fuel savings of individual vehicles are as shown in Table 2 below.

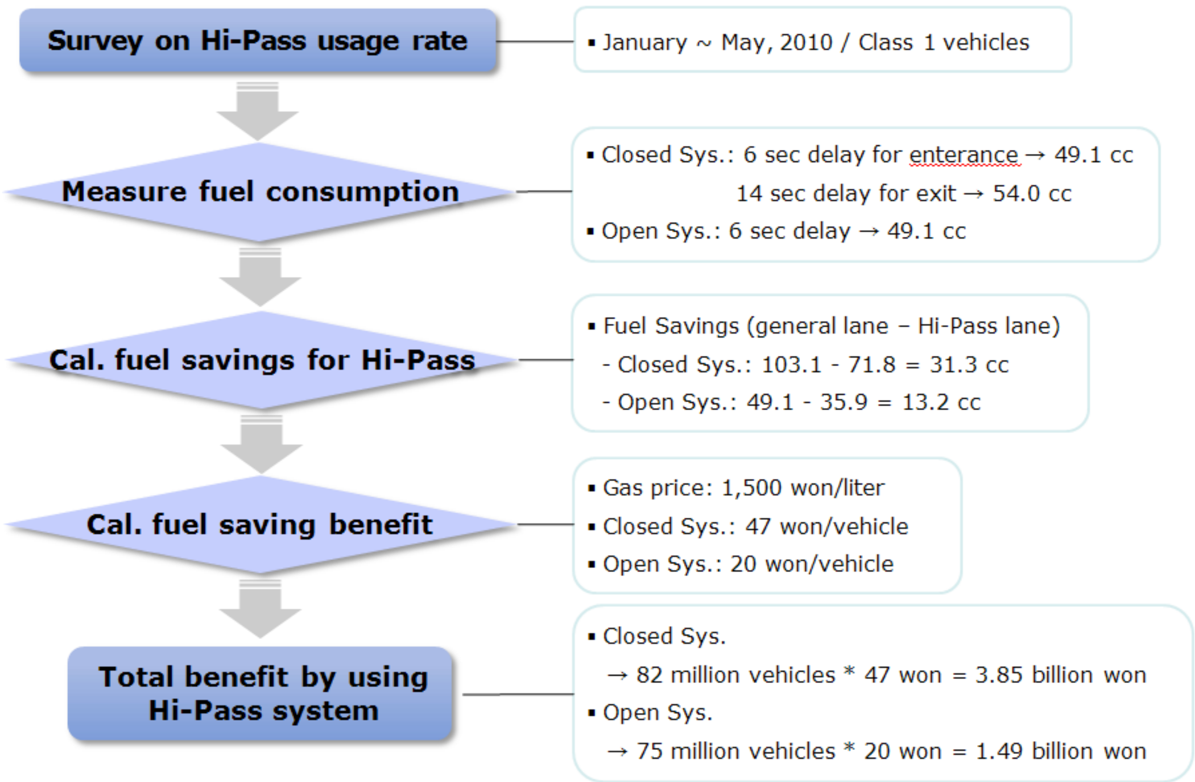

Figure 9 - Fuel Saving Analysis Procedure (First-class Vehicles)

Table 2 - Total Fuel Cost Saving Effects

Target (First Class)	Hi-pass Vehicle	Fuel Cost Saving (Billion Won)
All	157,000 vehicles	53.4
Closed- section	820,000 vehicles	38.5
Opened-section	750,000 vehicles	14.9

820,000 vehicles used closed-section Hi-pass lanes and the estimated fuel savings are 3.85 billion won. As ticketing time is about 6 seconds in the case of opened-section and assuming fuel consumptions is the same with closed-section entry, the traffic volume using Hi-pass in the opened-section stands 75 million units, reaching 14.9 billion won worth of fuel consumption savings. Consequently, the study estimates the fuel reduction effects from closed- and opened-sections of entire expressways, except for private-invested expressways are estimated to be a total of 53.4 billion won from January 1 to May, 2009.

4. CONCLUSION AND FUTURE CHALLENGES

The study implemented on-site driving tests, aiming to quantitatively prove the difference in fuel consumptions between Hi-pass lanes where vehicles pass through without stopping and general lanes that require speed reduction, stopping, and acceleration in using expressway toll gates. For on-site experiments, the study used vehicles that mounted experimental equipment to measure fuel consumptions and a test track equipped with a 100m exit, a toll gate model, and 500m entry.

The experimental conditions were classified into three types: First, (experiment 1) the case using Hi-pass lanes, second, (experiment 2) the case using entry of general lanes, and third (experiment 3), the case using exit of general lanes, and measured the fuel used by test vehicles according the conditions.

Summary of the experimental results are as follows:

First, the test vehicle that used Hi-pass lanes showed the least amount of fuel consumptions, while a 36.7% fuel consumption rate is demonstrated in the test vehicle that used a toll gate entry of general lanes and 50.4% increase using exit. The results demonstrate that when a vehicle stops for a toll payment and reduces/increases speed on the road, the idling will greatly affect fuel consumptions

Second, while a vehicle using closed-section Hi-pass lanes uses a total of 71.8cc fuel at exit, a vehicle using a general lane uses 103.1cc, suggesting that its consumption rate increases by 43.6% than the former case.

Third, according to fuel reduction effects estimation on Hi-pass lanes targeting first-class vehicle, which is the same type of vehicle to that of the test vehicles, during January to May in 2009 on actual expressways, the study discovered significant fuel reduction effects at about 53.4 billion won.

The study is of great significance in proving the fuel reduction effects of Hi-pass systems through on-site experiments and we revealed that the fuel reduction effects are relatively significant thanks experiments through Hi-pass in which executed under actual limited conditions.

The study believes that more dissections will be implemented through the collection of a variety of experimental data using various test vehicles and by considering geometric structural features of each toll gate in actual expressways.

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