EVALUATIONS AND IMPROVEMENTS OF THE KOREAN HIGHWAY ELECTRONIC TOLL SYSTEM

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(Received December 14, 2001)

In recent years, congestion pricing has gained popularity as a method for managing peak period congestion on major roads in urban areas. Especially, Intelligent Transportation Systems (ITS) technology has resulted in an electronic toll collection (ETC) system called “Hi-Pass” which is operated by the Korea Highway Corporation as a pilot program. Limited sections of highway have gained a good approval rating from motorists.

In this research, the Korean highway toll system was analyzed with respect to the brief legal history of the toll road, collection method and levels. In addition, the electronic toll collection policy for foreign countries including France, Norway, and Italy are investigated. The toll system of each country is clearly differentiated with regard to the institution, regulation and the economy.

After reviewing the pilot ETC program in Korea, the “Hi-Pass” system, several important factors were found. First, a more concrete marketing strategy for ETC users will be needed to encourage continued usage. Especially, frequent users and higher income users have more easily adopted the ETC system than others did. Second, in order to encourage the non-user to the ETC system, the costs of on-board units need to be reasonably low (about $50) and aggressive discounts (about 3–5% compared to 1% which are used currently) are needed.

Key Words: Congestion pricing, ETC, Korea, Highway, Hi-Pass

1. INTRODUCTION

Faced with the fast income growth, ongoing urbanization and rapid sub-urbanization (including five major new town development projects), it has become essential for the transportation professionals to evolve and adapt to the ever-increasing traffic demand in most Korean cities. As more vehicles are making more trips over longer distances, the major Korean highway systems face saturation and potential collapse.

Automobile ownership in Korea increased from just over 2 million in 1988 to over 11 million in 1999 resulting in 40% annual increase. During the same time, the capacity of road expansion resulted in an annual average increase of 3% in highways, and close to 5% on the national roads[1].

The above growth imbalance between road capacity and automobile increases resulted in severe traffic congestion on major highways in Korea. According to a recent study done by the Korea Transport Institute (2000), approximately 45% of national highways have experienced severe traffic congestion and almost 28% of the national roads in a similar situation. This severe traffic congestion in the Korean road system resulted in 13 billion US dollars in traffic congestion costs in 1998 and increased a further 1.5 billion US dollars annually[2].

Increasing road capacity requires a long period of construction time and massive amounts of capital. Not only the limitations of the budgets but also many mountain areas in the national territory make traffic congestion problems worse. According to these ever worsening transportation problems in Korea, toll road conceptions have been developed and implemented since the early 1970’s. The early toll road systems in the 1960’s are basically designed to recoup the capital outlays borrowed from international funds such as the World Bank, the Asian Development Bank, etc.

Recently passed by the Korean Congress, the “Transportation System Efficiency Act of 1999”[3] (hereafter The TSEA) specified the congestion pricing system as well as Intelligent Transportation Systems (ITS) be implemented to mitigate the ever increasing traffic problems in major metropolitan areas in Korea. The TSEA in Korea is quite similar to the Intermodal Surface Transportation Efficiency Act (ISTEA)[4] in the United States of America, and it was pivotal legislation. It wrapped up the highway construction program and introduced a new surface transportation policy - one where operations and management of the existing system are of paramount importance. The TSEA promoted research developments, to test and to evaluate advanced electronic systems.

By following the TSEA, the mayors of major cities in Korea can initiate the congestion-pricing concept in major roads in those cities that experience severe traffic congestion below 15km/hour during the peak hours[5]. Also, the TSEA encouraged national ITS programs. The electronic toll collection system is one of the major components of the Korean ITS program especially in highway management. The Korea Highway Corporation initiated the ETC demonstration program, the so-called "Hi-Pass" system that started in June 2000.

The rest of this study contains the following sections. In Section 2, we will investigate the brief history of toll collection methods in Korea. The ETC systems in various countries are reviewed in Section 3. The "Hi-Pass" toll collection demonstration system of Korea including the user and non-user survey results are presented in Section 4. The final section contains the conclusions.

2. TOLL COLLECTION SYSTEM IN KOREA

2.1 Existing toll collection method

The highway toll levied by the Korea Highway Corporation is based on the concept that the user benefiting from the road should pay for the service. The user benefit obtained by using the highway is normally estimated by comparing the user benefit from the alternative national road system, which is normally free to use. The amount of user benefit is 245 won/km, however, the actual toll levied is 34.8 won/km, which is almost one tenth of Japan and one third of France[6].

The reason for the far below user benefit concept of the current toll is that the highway toll is tightly controlled by various bodies of governments as well as the congress. It is based on the fact that the toll is significantly influenced by other various manufactured items as well as service prices.

Figure 1 presents the general process of the toll setting processes. The Korea Highway Corporation, the toll collection corporation, proposes the toll increase based on the balance sheets of the Corporation. After the toll increase proposal was submitted, the Ministry of Construction and Transportation (MOCT) recommend to the Toll Policy Committee, which consists of various groups including citizen's representatives. After close review by the Committee, the recommendation is submitted to the Party for coordination. Finally, the Ministry of Finance endorses it, and the MOCT approves the toll increases[6].

Entering into the tollgates, the highway ticket is given by the highway ticket issuing machine, and vehicles are classified automatically after identification by the vehicle classification system. When arriving at the tollgate of destination, drivers pay the toll by cash or toll card manually.

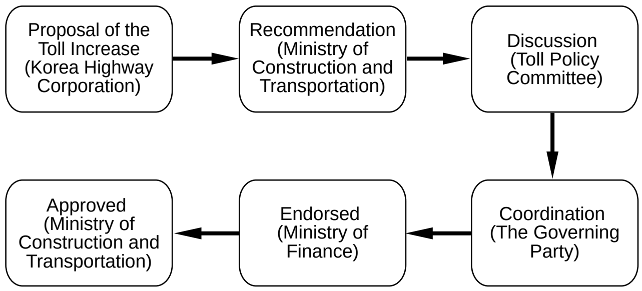

Fig. 1 The general process of toll increases

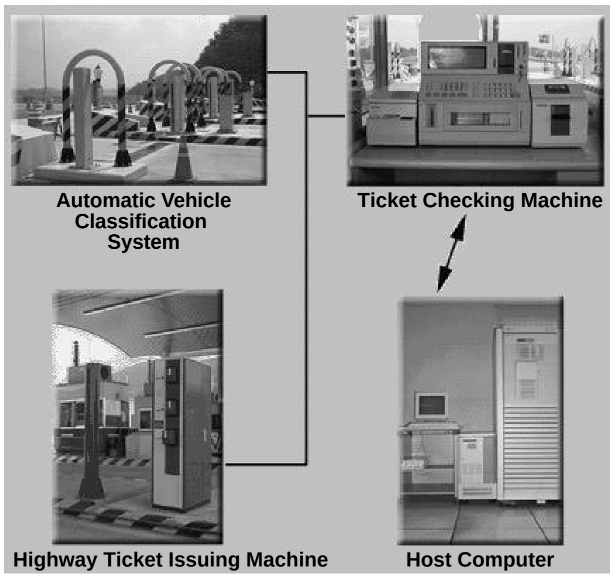

Fig. 2 The existing toll system in Korea

The tolls for the highway are discounted by 50% for light automobiles (below 800cc) to 20% for trucks carrying goods during off-peak hours (00:00 to 06:00). Also, the toll is discounted for the user who purchases toll cards in advance and uses the facility during the peak period (06:00 to 09:00 for morning peak and 18:00 to 22:00 for evening peak hour). There are clearly contradictions for the concepts of the congestion pricing[6].

Table 1 Toll discount system in Korea

Classification	Trucks during off-peak hours	Automobiles using toll card during peak hours	Light automobiles	Hi-Pass vehicles
Vehicles target	Trucks over 10 tons	Automobiles with toll card during peak hours	Light automobiles	Vehicle installed on-board unit
Hours	00:00 ~ 06:00	06:00 ~ 09:00 18:00 ~ 22:00	24 hours	24 hours
Discount rates	20%, 30%, 50%	15%, 30%	50%	1%, 2%, 3%
Method	ETC	Toll cards	Cash and toll cards	Hi-Pass card
Period	2000/01/10 ~ 2001/12/03	2000/01/10 ~	1996/06/01 ~	2000/07/01~

Table 2 Classification of vehicle classes for tolls

Vehicle class	Criterion
First class (1)	Passenger car, Bus (passengers < 16), Truck (gross load weight < 2.5t)
Second class (2)	Bus (17 ⊆ passengers ⊆ 32), Truck (2.5t ⊆ gross load weight ⊂ 5.5t)
Third class (3)	Bus (33 ⊆ passengers), Truck (5.5t ⊆ gross load weight ⊂ 10t)
Fourth class (4)	Truck (10t ⊂ gross load weight ⊂ 20t)
Fifth class (5)	Truck (20t ⊂ gross load weight)
Sixth class (6)	Passenger car less than displacement 800cc

The justification for the discount for trucks is that trucks carrying export/import commodities are encouraged to use the highway during the off-peak periods to avoid traffic congestion. In addition, the discount for the pre-purchased toll coupons is to reduce the processing toll collection times during the morning and evening peak periods. The discounted tolls for light automobiles encourage energy efficient small vehicles in urban areas.

As shown in Table 1 and 2, the toll collection methods which are specified by the "Toll Road Act of 1966" indicated that the toll classifications and the amount of tolls for each classification are calculated based on the type, weight and other elements of vehicles[7].

2.2 Congestion pricing in Korea

A distinction should be drawn between tolls to fund roadway construction and tolls to reduce congestion, as these have different objectives and impacts. Toll road funding essentially charges tolls to fund road improvements and to repay project costs. In contrast, congestion tolls are implemented on existing roads to reduce congestion, so tolls are high during peak hours and low or non-existent during off-peak hours. Congestion pricing is most effective when people have travel alternatives, such as alternate routes, alternate departure times, transit, or ridesharing.

As indicated in the previous section, the congestion pricing concepts are mainly discussed in the academic areas before the Congress of Korea passed the TSEA Act of 1999[8]. The previous research indicated that the traffic congestion at the tollgates for various highways in Korea was estimated at approximately 250 million US dollars in 1999 alone. In addition, this study revealed that the manual toll collection system needed 1.5 million US dollars for staffing costs alone in 1999. Ever increasing traffic on highways requires the expansion of tollgates as well as huge amounts of operating and maintenance expenses.

3. ETC SYSTEMS FOR FOREIGN COUNTRIES

3.1 Italy[9,10]

The Autostrade S.p.A. of Italy initiated the various ETC systems in Italy, such as Viacard, Telepass and Fastpay systems. Currently, 65% of all tollgates in the country use the automatic or semi-automatic electronic toll collection system for over 50% of vehicles.

Viacard Plus can be used not only for motorway tolls but also to pay for oil and fuel at participating ESSO and AGIP service stations. (Autostrade S.p.A. issues holders of the card a monthly invoice and statement. Payments are charged to your bank account.)

Telepass is an electronic payment system, which enables users to drive through special toll lanes without stopping. The service is available to individuals using private vehicles. The electronic device installed inside the vehicle allows users to drive through the Telepass lanes when they are entering or exiting the motorway. The toll fee is automatically calculated and charged to the users' bank account on a three month basis.

The automatic motorway payment system was designed and produced by SSB - Società per i Servizi Bancari S.p.A, in cooperation with Autostrade S.p.A. Payment is made using normal ATM bank cards (such as "Bancomat") issued by participating banks. If you have a Bancomat card, ask your bank whether you can use it with the Fastpay system. Use your card to pay tolls of up to Lit. 120,000 (Euro 61.97) per trip (there is no need to use a personal identification number). To date, 685 banking organizations have joined the scheme and the number is set to rise even further.

3.2 France[9]

The implementation of ETC on French motorways was made by seven public and semi-public private agencies under the ASFA. Approximately 6,700km among 7,400km of highways are controlled by the ASFA. The "TIS" of France has operated since 1995.

The Tag and smart card method for the on-board units were adopted, and the Tags are operated with batteries. The Tag and smart cards cost around 180 to 300 Fr for leasing. The toll payment methods combine pre and post-paid, and the number of toll classification are five vehicle types.

In order to avoid a monopoly of the supplier, France adopted the multi-supplier method. Approximately 10–30 percent of the ETC systems are from a single agency.

3.3 Norway (Q-FREE)[9,11]

The toll-ring system has been very successful at raising revenue with a low cost by using innovative and flexible technology. However, it has had only modest success of reducing traffic into the town center. The Trondheim Toll Ring has twelve toll plazas, which cordon the central area of Trondheim where 50,000 people live. The critical success factor is that most vehicles drive through a toll plaza without stopping. Vehicle identity is recorded electronically by scanning a "Q-FREE" tag attached to the inside of the front windshield. Tolls are recorded only on entry into the ring and exiting from the area is free.

The peak period pricing is a feature of the electronic tag system. Transit, disabled-sticker vehicles and motorcycles pass free. Trucks pay double. After 5 p.m. on workdays, and on weekends and holidays, travel is free for all vehicles. For users without an electronic tag, there is a coin or magnetic-card payment option at each toll station. These are accessed through a pullover similar to a bus bay in terms of design. License plates are photographed to track vehicles avoiding payment. At two of the twelve tollbooths, there are manual attendants. Overall, only one in five entries to central Trondheim is without a tag, and less than one in ten does so in the peak period.

The Q-FREE tag user is billed either through monthly automatic debiting of a checking account, or through debiting a prepaid account (e.g., a $100 prepaid credit is reduced by $1.60 on each entry). Half of the electronic tag subscribers pay by automatic debiting of their checking account each month. Most others prepay $100 (500NK) on a regular basis. The remaining vehicles pay manually.

4. PILOT PROGRAM FOR ETC IN KOREA (HI-PASS)

The Korea Highway Corporation initiated the demonstration program called "Hi-Pass" for the electronic toll collection system in June 2000. The ETC system can exchange toll related information between OBU installed in vehicle that passes through the tollgate on the highway.

4.1 Current status of Hi-Pass program[12]

As shown in Figure 3, currently the Hi-Pass ETC program initiated by the Korea Highway Corporation installed three tollgates around the Seoul metropolitan areas such as Pangyo, Cheongge and Seongnam.

Fig. 3 The location of three tollgates

The targeted vehicle classifications for the Hi-Pass demonstration programs are three classes, namely, first class for automobiles, third class for regular city buses and sixth class for light automobiles. As of now, approximately 10,000 on-board units are installed for various vehicle classes. The prepaid “Hi-Pass” cards are used for all classes except regular city buses, to which apply a postpaid method.

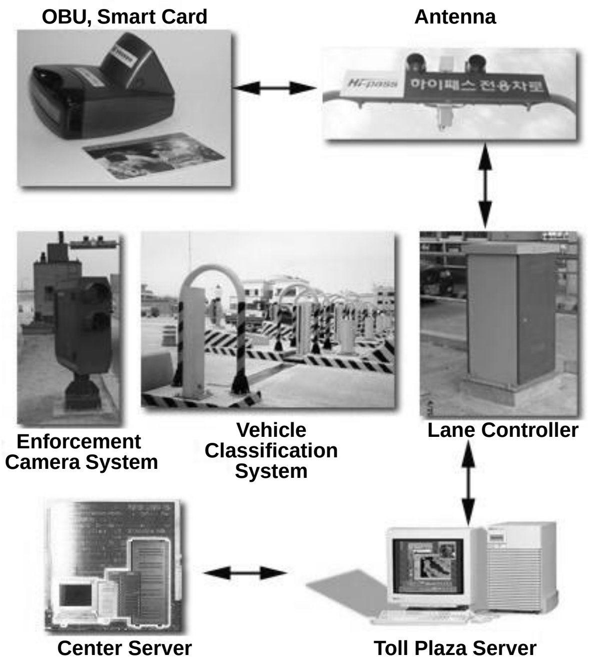

Fig. 4 Hi-Pass system configuration

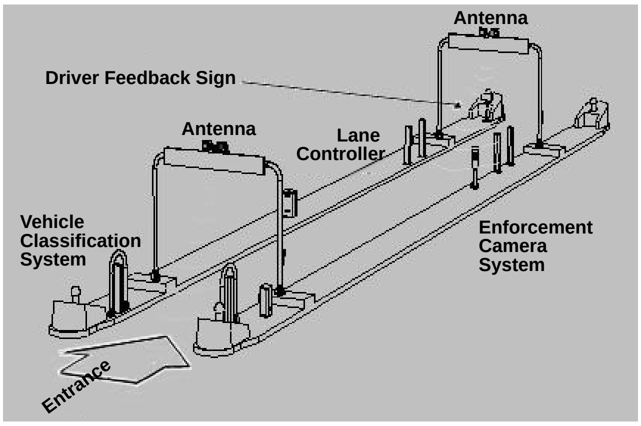

Fig. 5 Hi-Pass system concept

The specifications of the Korea ETC systems are quite similar to other foreign countries. Figures 4 and 5 show the tollgate structure, the Hi-Pass system configuration and concept of the Hi-Pass system. The Hi-Pass tollbooth was built by setting up a square bar from origin tollbooth fixed antenna at the center. Figure 6 shows that Hi-Pass system is operated single lane in each direction.

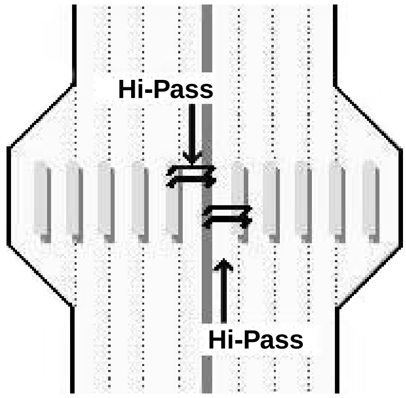

Fig. 6 Location of the Hi-Pass lanes

In the communication link of ETC application, active communication mode is adopted in Japan’s DSRC Standard (ARIB T55), while the passive communication mode is adopted in the European DSRC Standard (ENV 12253). Both the active mode and passive mode have clear advantages[13]. The Korea ETC pilot program adopted the passive communication mode for its initial testing, however, the active mode is being tested for evaluation purposes.

Table 3 The traffic characteristics of the demonstration sites

TG	Cheongge	Pangyo	Seongnam
Operation type	Open	Close	Open
Number of tollbooths	10 – 12	6 – 8	7 – 9
Average daily traffic	114,048	63,598	67,812
Peak hour volume	4,896	3,375	2,895
Peak hour	08 –09	07 – 08	08 – 09

Table 3 shows the general traffic characteristics of three sites for the ETC demonstration project initiated by the Korea Highway Corporation. Table 4 shows the vehicle types and the utilization status of the ETC demonstration program. Because of the nature of the pilot program, only 4% of the total vehicles used the ETC gates. The “Hi-Pass” tollgates in three demonstration sites only carried about 30% of the transactions per hour per lane compared to the conventional non-ETC tollgates. At least, over 30,000 vehicles with the ETC equipped vehicles are needed to carry more transactions per hour per lane than the manual gates.

For using the Hi-Pass system, a driver should go through the following process. Drivers apply for the Hi-Pass application form at the spot installing the OBU. As

Table 4 The ETC utilization of the ETC demonstration program

TG	Cheongge	Pangyo	Seongnam	Total
Used	4,261	4,348	1,981	10,590
Unused	121,499	65,008	71,215	257,722
Total	125,760	69,356	73,196	268,312
Rate of utilization (%)	3.4	6.3	2.7	3.9
Transaction rate per lane (%)	35	40	19	31

the drivers' personal information is identified, drivers should pay the rental fee of the OBU and prepaid Hi-Pass card. After the OBU is installed the Hi-Pass sticker is placed on the front window of the car.

4.2 Evaluation of the ETC demonstration program

In order to evaluate the ETC pilot program of the Korean highway system, two field studies were carried out. First, the traffic operating study such as average waiting times and average queue length to pay tolls on three demonstration sites before and after the ETC pilot program were performed. Tables 5, 6 and 7 show the average waiting times and queue length for the three sites before and after the ETC program. As the tables clearly show, the measure of effectiveness of the ETC program is very little or none on all three sites. The reasons for this low effectiveness are the fact that the number of ETC equipped vehicles is very limited which accounted for just over 4% of all vehicles. As indicated before, at least over 30,000 ETC equipped vehicles are needed for any significant impacts of the ETC program.

Second, the customer satisfaction survey for the user and non-user of the ETC program was carried out to evaluate the future success of the ETC program. The

Table 5 The measure of effectiveness at Cheongge

Classification	After		Before	
	Waiting time	Queue length	Waiting time	Queue length
West-bound, peak	45.713	6.924	52.598	6.539
West-bound, off-peak	34.655	3.403	37.685	4.286
East-bound, peak	121.335	16.569	154.520	23.106
East-bound, off-peak	39.932	5.269	15.195	1.603

Table 6 The measure of effectiveness at Pangyo

Classification	After		Before	
	Waiting time	Queue length	Waiting time	Queue length
North-bound, peak	14.998	1.831	15.862	1.971
North-bound, off-peak	30.15	2.313	12.242	3.801
South-bound, peak	23.206	9.507	26.262	12.598
South-bound, off-peak	9.081	2.575	41.197	1.313

Table 7 The measure of effectiveness at Seongnam

Classification	After		Before	
	Waiting time	Queue length	Waiting time	Queue length
North-bound, peak	35.105	4.011	33.052	3.404
North-bound, off-peak	25.124	2.206	18.001	1.276
South-bound, peak	16.949	1.960	28.159	2.549
South-bound, off-peak	7.899	0.833	25.848	1.979

mail-back questionnaires were distributed to 6,800 ETC users asking questions such as the level of satisfaction of the ETC and the reason for the answers. In addition, a non-user survey was carried out for over 15,000 users. However, only 680 were returned resulting in a 4.5% response rate.

The correlation analysis is carried out using 2,000 ETC users returned surveys. Table 8 shows the results of the correlation analysis. Not surprisingly, among six variables, the user who used the highway frequently is most statistically significant for the satisfaction of the ETC program. In addition, the occupation is the least significantly related for the satisfaction of the ETC program. Other things being equal, the frequent user, higher income user, and peak hour user showed higher satisfaction of the ETC program.

Table 8 Correlation analysis for the user of the ETC system

Variables	Coefficient	P-value
Age	0.073	0.0196
Occupation	0.034	0.2833
Income	0.076	0.0154
Trip purpose	0.052	0.0933
Frequency	0.151	0.0001
Peak period	0.088	0.0050

The same analysis as the user of the ETC program was conducted for the non-user of the program. As indicated before, the response was quite low, accounting for only 4.5%, so these results are very limited for the policy aspects of the ETC program.

As Table 9 indicates the renting fee of the OBU (currently about $100) and toll discount rates (1%) are the most critically discouraging variables for the non-user of the ETC system. The most frequently cited categories for the renting fee of the OBU are around $50 and 3-5% toll discount rates needed to change the ETC system for the non-user's point of view.

Table 9 Correlation analysis for the non-user of the ETC system

Variables	Coefficient	P-value
Age	−0.108	0.1287
Occupation	0.103	0.1456
Trip purpose	0.170	0.0159
Renting fee of the OBU	0.233	0.0009
Discount toll rate	−0.348	0.0001

5. CONCLUSIONS

The conversion of conventional manual tollgates to the ETC is seemingly an inevitable trend. How quickly it occurs remains to be seen. This paper analyzed the ETC demonstration program initiated by the Korea Highway Corporation. From the ETC demonstration program of Korea, it is apparent that the ETC demonstration program has been quite successful with respect to the users of the system. Because of the nature of the demonstration program, there is very little or no significant system efficiency for the ETC system. Also personal information security remains to be solved. In order to implement the ETC system successfully, the following five main points should be emphasized.

(1) At least 30,000 or more vehicles are needed to achieve any significant improvement of current traffic operation in tollgates on the three demonstration sites.
(2) A more concrete marketing strategy for ETC users will be needed to encourage continued usage. Especially, frequent users and higher income users more easily adopted the ETC system than others did.
(3) In order to encourage the non-user to adopt the ETC system, the costs of OBU should be reasonably low (about $50) and a more aggressive discount (about 3-5% compared to 1% which is current) are needed.
(4) Even though the technical specifications of the demonstration program of ETC were satisfactory, there are many issues to be resolved such as interoperation to other agencies and international standards dwell on the privacy issues.
(5) Finally, the greatest benefits provided by the ETC systems are to user of the system and society. However, the benefits of the toll agencies are negative, so the agencies are reluctant to increase the ETC systems. To successfully implement the ETC system nationwide, intergovernmental cooperation and coordination are critically important.

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ACKNOWLEDGEMENTS

This research has been performed as part of the Advanced Highway Research Center project funded by Korea Ministry of Science and Technology, Korea Science and Engineering Foundation.