THE EFFECTIVENESS OF CONGESTION PRICING IN SEOUL --THE CASE OF NAMSAN 1&3 TUNNELS IN CBD -

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abstract: To solve the congestion problem in Seoul, the government started charging, from November 11, 1996, 2,000 won tolls for 1-2 occupant vehicles passing Namsan 1&3 tunnels from 7 am to 9 pm, major arterial linking the southern part of Han-river with the old downtown. The evaluation results are encouraging and reveal many promising characteristics. Therefore, the authors recommend that congestion pricing scheme should be extended to the other major congested arterial, and that, for responding to the equity issues related with congestion pricing, all the revenues be invested for improving the service quality of mass-transit systems in Seoul.

1. INTRODUCTION

The city of Seoul is over 600 years old and the size is 605 km^2, of which 374.5 km^2 is available for human activities. Since 10.6 million population reside in a small area, the density is very high. The streets run radially toward the center of the city, so that over 25% of trips are concentrated at the center. Among these trips, 25% just pass through the center, causing a severe traffic congestion in CBD. In addition, increasing travel demand caused by continuing economic growth and suburban new towns aggravates traffic condition all over in Seoul.

In 1994, the Seoul Metropolitan Government (SMG) invested 48% of its annual budget for subway construction and road building to relieve traffic problems. Notwithstanding these massive construction projects, it is not expected that facility supply will guarantee us congestion-free streets in the near future. Coping with this unamicable situation, the city starts to have interests in TDM, especially in congestion pricing(from now on CP) among many TDM techniques. They perceive that it is the most effective way to control auto-uses, as well as to reflect locational and time variations of traffic congestion. CP, however, was not a popular alternative. It was considered in many major cities in the world, but few cities adopted it. Only, Singapore experienced a sizable success relieving traffic congestion through Area License Scheme in CBD.

The purpose of this paper is to evaluate the effectiveness of congestion pricing scheme in Namsan 1,3 tunnel in Seoul after one month of its implementation. The city government will decide the expansion of congestion tolled sites based on the results of the Namsan 1,3 tunnel case. The study consists of 5 parts. They includes 1) the background of introducing CP in Seoul: traffic situations in Seoul, 2) the contents of the scheme, 3) framework of analysis and research method, 4) analysis results, and 5) summary and conclusion.. The effectiveness is tested for the changes of six parts: 1) traffic volume and average speed of Namsan 1 and 3 tunnel corridors, 2) traffic volume of right after and before congestion charging in Namsan 1 and 3 tunnel, 3) traffic volume and average speed of four alternative routes, 4) total traffic volumes in a network including Namsan 1,3 tunnel and alternative routes, 5) number of users of alternative modes, and 6) shares of untolled cars.

2. BACKGROUND OF INTRODUCING CP IN SEOUL:

2.1. Traffic Situation in Seoul

The traffic situation in Seoul is serious.. According to the studies conducted by SMG in 1994, the average speed is only 23.18km/h for autos, and 18.42km/h for buses. In the CBD area, it marked 20.04km/h for autos, and 23.40km/h in non-CBD areas. Comparing with the previous year 1993, the auto speed has declined by 1.5%, while the bus increased by 8.2%. Although there is a sign that traffic conditions for bus is improving, the traffic delay is still a very serious problem (See Table 1).

(Table 1 : auto-speed change per year) (Unit:km/h)

Division		1990	1991	1992	1993	1994	Comparing 1994 with 1993
Auto-vehicle	All	24.22	21.57	22.62	23.53	23.18	-0.35(-1.5%)
	CBD	16.40	17.66	19.28	19.97	20.04	+0.07(+0.4%)
	Non-CBD	25.78	21.89	22.87	23.79	23.40	-0.39(-1.6%)
Bus		18.80	18.15	16.88	17.02	18.42	+1.4 (+8.2%)

Source: SMG, 1994a

The reasons of this severe congestion are many-folded. First, it arises from the low capacity of transportation systems. About 19% of the land in Seoul is paved, compared with 20% to 35% in many American and European Cities. Since the vacant land is too little and land price is so high, building sufficient roads are financially infeasible for Seoul (See Table 2). According to a study on the mode uses of CBD workers, only 35% of auto-owners use cars for their commuting mainly because of traffic congestion and parking space shortages, which implies that there are plenty of latent demand of automobiles waiting for their chances of driving when new roads are supplied.

(Table 2: Road Capacity)

Division	1989	1991	1996	2001	Increase rate of annual mean (%)
Road-area(km^2)	67.68	69.31	76.1	82.4	1.7
Efficient-area(km^2)	43.45	44.5	50.0	55.0	2.1
Traffic capacity (1,000 vehicle)	3,853	4,518	6,727	10,000	8.3
Peak-hour capacity (1,000 vehicle)	593	632.5	942	1,400	8.1

Source: SMG, 1994b

Second, in the last 15 years, auto-ownership in Seoul has grown annually over 20%, which amount to 2 million vehicles on 1995 (See Table 3). There were sixty thousand vehicles in 1970, and the number increased 3.5 times for ten years to 204 thousand in 1980. The number of vehicles, however, has started to increase rapidly since the latter part of 1980's. Though the yearly growth rate has been getting slow from 1990, the number keeps growing. Even if it is hoped that travel demand increase will be offset by street capacity gains resulting from planned completion of 400km or more subway construction, attracting auto-users to subway would not be an easy task.

(Table 3) Trend of the number of vehicle ownership

	1970	1980	1990	1995
Total number of vehicles(1000)	60	207	1,193	2,043
auto	18	99	826	1,520
auto per 1000 Population	10.9	24.7	109.4	128.0
auto per 1000 hhold	54.7	112.4	358.4	593.0

Source: SMG, 1995

In addition to rapid increases of the auto-ownership, the traffic congestion is attributed to a compounding of growth in daily person trips and mode use frequencies, as economic conditions in the region have been improved consistently over the last 20 more years. During the 1989-1991 period, daily person trips increased 3.8%, and mode-use frequency increased 2.0%. Discretionary trips for shopping and recreation rather than compulsory trips consist of major parts of these growth.

2.2. Transit Policy measures to relieve congestion

To cope with traffic congestion caused by increasing travel demand, SMG depends heavily on building subways. As the Table 4 shows, SMG expects that in spite of vehicle growth to over 3 million by 2001, subway share will increase from 26% in 1993 to 50% in 1997, and to 75% in 2001. However, automobile is the most predominant travel mode in terms of convenience and comfort, vigorous investment on subway would not automatically guarantee relieved traffic problems in Seoul Metropolitan Area.

(Table 4: Transportation Indicator of Seoul)

Division		1993	1994.12	1995	1997	1999	2001
Population (1,000 population)		10,925	10,970	10,993	11,000	11,230	11,400
Travel Popualtion (1,000 population)		26,240	26,751	27,258	28,253	29,170	30,020
Automobile (1,000 vehicle)		1,750	1,944	2,161	2,571	2,885	3,161
(Private car)		(1,277)	(1,421)	(1,590)	(1,905)	(2,150)	(2,374)
Ratio of road(%)		19.3	19.7	20.2	20.9	21.9	23.0
Travel-speed(km/h)		23.53	23.18	23.4	24.0	24.0	24.0
Subway(km)		133.0	133.0	216.5	278.0	400.0	400.0
Mode Share(%)							
	Subway	25.6	28.7	38.5	50.0	75.0	75.0
	Bus	38.6	37.0	31.5	26.2	10.0	10.0
	Taxi	11.8	10.4	8.5	5.0	4.0	4.0
	Private-car	14.2	14.2	13.0	11.5	7.0	7.0
	Etc	9.8	9.7	8.5	7.3	4.0	4.0

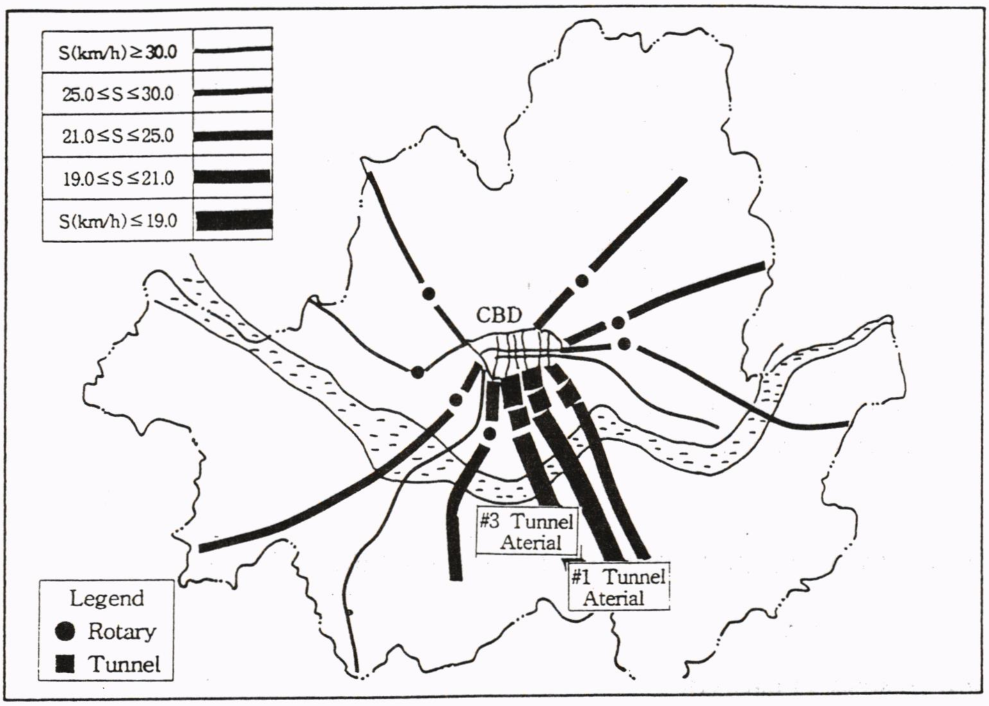
Source: SMG, 1995

Reviewing the experiences of other big cities, heavy investment on public transit is not cost-effective (Downs, 1992). In other words, switching people from automobiles to inferior subway would not occur easily unless accompanied with transportation demand management measures affecting travel behavior and with system management skills.

3. CONTENTS OF NASAN TUNNEL CONGESTION PRICING SCHEME

3.1. Selecting the Exhibition Sites: Namsan 1 and 3 Tunnel

As the exibition sites, Namsan 1,3 tunnels are chosen among major arterials linking outskirt areas to CBD (See Figure 1). There are several reasons to choose these sites for the exibition.. First of all, they are located in the middle of the corridors which are very congested throughout all day long. These corridors are notorous for excessive private auto vehicle uses. The private autos consist of 90% of total traffic volume, which is the highest among all the corridors linked to CBD, and single passenger autos account for 78% among the private auto vehicles.



(Figure 1) Namsan 1&3 Tunnel Sites and Traffic Situation

Second, the relative time losses of bus passengers in these corridors are the most serious compared with those of bus passengers in the other corridors. By imposing congestion tolls on 1-2 passenger private autos, it will restore the relative time losses of bus passengers using Namsan tunnels.

Third, the sites have merits in terms of administrative costs.. Toll booth facilities for cash collection have existed in Namsan 1,3 tunnel, where 100 won tolls were collected for 20 years until October 1996 to recover the construction costs.

3.2. Components for Implementation

The SMG started charging, from November 11 (Monday), 1996, 2,000 won (US $2.2) congestion tolls for 1-2 occupant private auto-vehicles using Namsan (South-Mountain) 1 and 3 tunnels, major arterials linking the southern part of Han-river with the old downtown. Prior to the implementation, seven days were reserved for the public notice.

The charges are collected for both directions per entry from 7:00 to 21:00 during weekdays, and from 7:00 to 15:00 on Saturday. Sunday and national holidays are free of charge. The violation penalty amounts to 10,000 won (US $11). All the private auto-vehicles with 1-2 passengers (including driver) have to pay tolls for using tunnels. However, following vehicles are exempted from charge:

* 3 or more passenger private auto
* taxi, all kinds of buses, vans, trucks
* diplomats' vehicle
* reporter's vehicle
* government vehicles
* ceremony vehicles

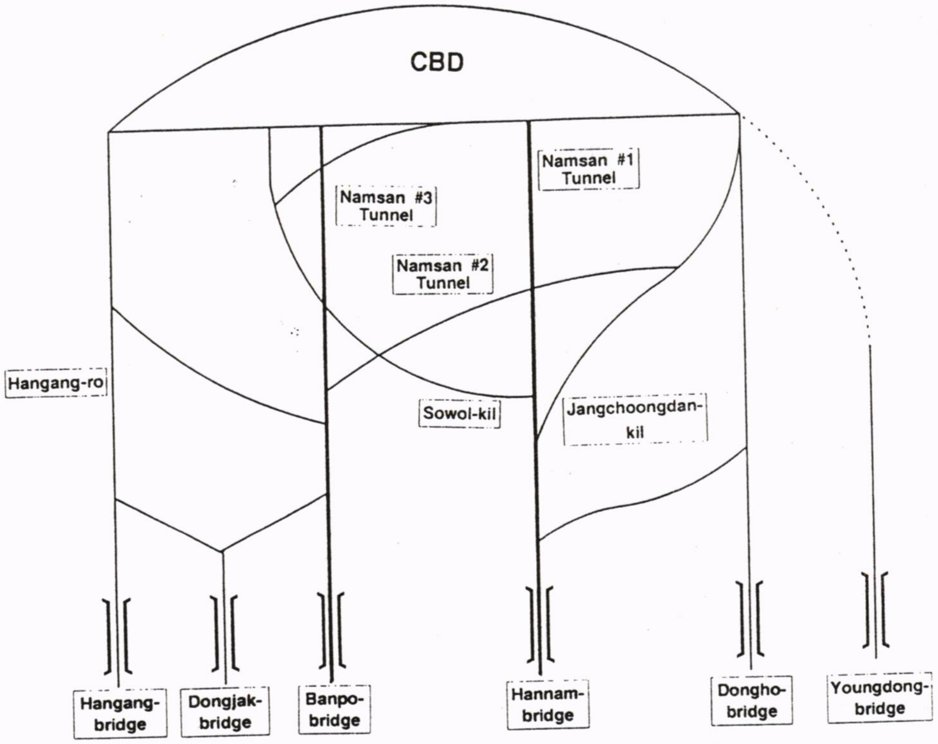
4. ANALYSIS FRAMEWORK & SURVEY METHOD

4.1. Analysis Framework

The main purpose of CP is to relieve traffic congestion by reducing vehicle volumes. Therefore, where the demand curve meets the marginal cost curve in a forward bending section, it should be verified that traffic volumes decrease while traffic speed improve on the corridor where the charge is levied. On the other hand, where the demand curve crosses with the marginal cost curve in the backward bending section, we can expect that traffic volumes and speed increase simultaneously.

In general, congestion tolls are imposed when congestion occurs.. Accordingly, tolls are collected in a limited time base, and many traffics tend to concentrate on the time period just before and after the tolls levied. It is desirable that the travel time shift occurs by collecting fees. However, if too many drivers take time-shift options, the network-wise trip reduction may not result.

Since Namsan 1,3 tunnels have several alternative routes, the congestion toll may worsen traffic situation in those routes (See Figure 2). In which case, the pricing only plays a role of shifting congestion without improving the traffic conditions in the network. Therefore, for validating the effectiveness of the scheme, it is necessary to check the changes of traffic situation in those alternative routes.



<Figure 2: Namsan 1 and 3 Tunnel Site Map)

If the auto vehicle drivers want to escape the congestion charge, majority of them would choose alternative travel modes instead of giving up the travel themselves. There are several alternatives of low-occupant auto-vehicles in Seoul. Currently, 6 subway lines are in operation, and almost 9,000 buses serve about 430 routes, carpools and taxis are options to use as well.

In summary, the effectiveness of Namsan 1,3 tunnel congestion pricing scheme is determined as a result of the changes of five parts:

1) trip reduction impacts: traffic volume and speed of Namsan 1 and 3 tunnel corridors / the composition of tolled and untolled vehicles;
2) time shift impacts: traffic volume of just before and after congestion tolls in Namsan 1,3 tunnel;
3) route change impacts: traffic volume and speed of alternative routes;
4) mode shift impacts: number of users of alternative modes;
5) network impacts: aggregate traffic volume changes in Namsan 1,3 tunnel and alternative routes together.

4.2. Field Survey Method

1) Traffic Volume of Namsan 1,3 Tunnel

The field surveys were conducted by Seoul Development Institute and Seoul Metropolitan Government together. The before-survey was conducted on Nov. 5 and 7, 1997 from 06:00 to 22:00. The time period covers one hour right before and after the congestion toll period. After-surveys were implemented through Nov. 11, 1996 to Dec. 5, 1996 during the same period of time. The survey includes traffic counts by vehicle types, and vehicle riderships of private autos and buses.

2) Traffic Speed of Namsan 1,3 Tunnel

Traffic speeds in Namsan 1,3 Tunnels were measured using the floating-car method through Nov. 11, 1996 to Dec. 5, 1996 during the same period of time. The survey section runs from the toll gate to the southern entrance of Hannam Bridge for Namsan 1st tunnel, and from the toll gate to the southern entrance of Banpo Bridge for Namsan 3rd tunnel. (See Figure 2)

3) Traffic Volume and Speed of Alternative Routes

For checking the traffic situation of alternative routes, four routes were selected, which are Hangang-Ro, Sowol-kil, Jangchoongdan-kil, and Namsan 2nd tunnel (See Figure 2). Traffic volumes and speeds were surveyed using the same methods mentioned above. For the volume survey, only private passenger vehicles were counted, since other type vehicles would hardly change their routes for escaping tolls. The survey period is the same as the above.

4) Ridership Changes of Subway, Bus, and Carpool

The ridership changes of alternative modes were surveyed for one week after the implementation. For subway, the ridership changes of No. 2 and 3 lines were surveyed, and for buses all the bus lines passing Namsan 1,3 tunnels were investigated. Carpool survey was conducted only during the morning peak period from 07:00 to 09:00.

5. ANALYSIS RESULTS

5.1. Changes of Traffic Situation in Namsan 1,3 Tunnels

1) Changes of Traffic Situation in Namsan 1st Tunnels

Table 5 shows the changes of traffic volume in Namsan 1st tunnel corridor.. The traffic volumes were 39,982 vehicles on average during the tolled time period before the congestion toll charged, and dropped quickly to 29,510 (26.2% reduction) in one week. In the second and third week, the amount of vehicle trips were reduced to 29,703 (25.7% reduction), and 31,065 (22.3% reduction), respectively. In the fourth week, the amount recorded 30,292 (24.2% reduction). The results imply that the congestion toll contributed to a significant reduction of the traffic volumes, but drivers adapted to the new environment by returning slowly back to the tunnel. Reviewing the traffic volume changes for each direction, we found that in-bound traffics were affected more from the congestion toll than the out-bound traffics.. The in-bound traffic was reduced 26.9%, while out-bound traffic reduced 21.2%

〈Table 5〉 Traffic Volume Changes in Namsan 1st Tunnel Corridor

	Daily Ave. Traffic Volume during the tolled time period								
	before	1st week	change (%)	2nd week	change (%)	3rd week	change (%)	4th week	change (%)
total	39,982	29,510	-26.2	29,703	-25.7	31,065	-22.3	30,292	-24.2
in-bound	21,352	15,249	-28.6	15,288	-28.4	15,917	-24.5	15,606	-26.9
out-bound	18,630	14,261	-23.5	14,415	-22.6	15,148	-18.7	14,686	-21.2

The vehicle speed in the corridor increased from the daily average 25.3km/h before implementation, to 34.8km/h (37.5% improvement) in the first week, to 43km/h (69.5% improvement) in the second weeks, to 40.0km/h (58.1% improvement) in the third week, and to 35.7km/h (41.1% improvement) in the fourth week (See Table 6). The increase of vehicle speed is skyrocketing compared with the changes of traffic volumes. It is expected that the speed in the corridor will be stabilized around 35km/h.

〈Table 6〉 Speed Changes in Namsan 1st Tunnel Corridor

	Daily Ave. Traffic Speed(km/h)								
	before	1st week	Change (%)	2nd week	Change (%)	3rd week	Change (%)	4th week	Change (%)
tot.	25.3	34.8	+37.5	42.9	+69.5	40.0	+58.1	35.7	+41.1
in-bound	35.9	46.1	+28.4	46.2	+28.7	48.4	+34.8	44.0	+22.6
out-bound	14.7	23.5	+59.8	39.5	+168.7	31.6	+114.9	27.3	+85.7

Reviewing the speed change for each direction, the speed for the out-bound traffic was significantly improved. This is not surprising because there is a reasonable reason for the result. That is, the out-bound congestion caused by traffic weaving problem in the intersection was somewhat relieved by the traffic volume reduction.. In fact, the level of service in a weaving section is mainly dependent on the traffic volume passing the section. The reduction of the out-bound traffic contributed to mitigate the congestion in the weaving section, and consequently improved the travel speed on this corridor.

2) Changes of Traffic Situation in Namsan 3rd Tunnel

Table 7 shows the changes of traffic volume in Namsan 3rd tunnel corridor. Previously, the traffic volumes were 50,422 during the tolled time period, and then dropped quickly to 39,147 (22.4% reduction) in one week. In the second and third week, the vehicle trips declined to 38,848 (23% reduction), and 37,426 (25.8% reduction), respectively. In the fourth week, the trips reached to 37,620 (25.4% reduction).

<Table 7> Traffic Volume Changes in Namsan 3rd Tunnel Corridor

	Daily Ave. Traffic Volume during the tolled time period								
	before	1st week	Change (%)	2nd week	Change (%)	3rd week	Change (%)	4th week	Change (%)
tot.	50,422	39,147	-22.4	38,848	-23.0	37,426	-25.8	37,620	-25.4
in-bound	26,416	21,317	-19.3	21,367	-19.1	20,913	-20.8	20,613	-22.0
out-bound	24,006	17,830	-25.7	17,481	-27.2	16,513	-31.2	17,007	-29.2

The vehicle speed in the corridor increased from the daily average 17.8km/h before the implementation, to 37km/h (107.9% improvement) in the first week, to 34.6km/h (94.4% improvement) in the second week, to 33.0km/h (85.4% improvement) in the third week, and to 31.5km/h (77% improvement) in the fourth week(See Table 8). The speed tends to decrease as days go by, but not less than 30km/h. Unlike Namsan 1st tunnel corridor, the in-bound speed was significantly affected by the traffic reduction. However, the small improvement on the out-bound corridor was mainly caused by an unreasonable junction between Namsan 2 and 3 tunnels near the signalized intersection, so the traffic reduction of this direction did not contribute to relieve the congestion.

〈Table 8〉 Speed Changes in Namsan 3rd Tunnel Corridor

	Daily Ave. Traffic Speed(km/h)								
	before	1st week	Change (%)	2nd week	Change (%)	3rd week	Change (%)	4th week	Change (%)
tot	17.8	37.0	+107.9	34.6	+94.4	33.0	+85.4	31.5	+77.0
in-bound	20.7	50.3	+143.0	45.4	+119.3	44.9	+117.0	44.3	+114.0
out bound	14.9	23.5	+57.7	23.8	+59.7	21.1	+41.6	18.7	+25.5

3). Share of the vehicles exempted from the toll

Table 9 shows the shares of exempted vehicles before and after the toll levied. According to the toll booth survey conducted during 8 hours (07:00-09:00, 13:00-15:00 and 17:00-21:00) from Nov. 11 to Dec. 5, the number of 1-2 occupant passenger vehicles recorded 36,062, which accounts for 68% of the total vehicles using Namsan 1,3 tunnels. After the congestion pricing, however, the share of other vehicles increased from 32% to 57%, which means that there was a significant increase of carpools, vanpools, trucks, taxis, etc. It can be also said that more emergent-purpose vehicles used these corridors efficiently.

<Table 9>: The Share of Untolled Vehicles in Namsan 1,3 Tunnel

	before		one month after	
	1-2 occupant passenger car	others	1-2 occupant passenger car	others
in	19,631	9,185	10,416	14,255
	68%	32%	42%	58%
out	16,431	8,160	10,226	13,174
	67%	33%	44%	56%
total	36,062	17,345	20,641	27,429
share	68%	32%	43%	57%

5.2. Time Shift Impacts

It was expected that the vehicle trips passing Namsan 1&3 tunnels just before and after the toll period would increase due to many time shifting drivers to escape the charge. Table 10 shows the traffic volume changes in Namsan 1st tunnel during the time period of 06:00-07:00 and 21:00-22:00. In the fourth week, the traffic volume decreased 7.7% unexpectedly in the morning, while increased 37.8% at the night time period.

〈Table 10〉 : Traffic Changes before/after the toll start in the 1st Tunnel

	Vehicle Trips (Thursday)								
	before	1st week	change (%)	2nd week	change (%)	3rd week	change (%)	4th week	Change (%)
morning	3,184	2,316	-27.3	2,705	-15.1	3,090	-3.0	2,940	-7.7
night	2,831	2,315	-18.3	3,422	+20.8	2,902	+2.5	3,901	+37.8

Table 11 shows the time shift impact at Namsan 3rd tunnel. On average, the traffic volumes jumped over 50% for both in the morning and at night. The first week experienced the biggest shift probably because of the shock, but time shift impacts became weaker. There exists a significant difference in the shifting rates between two sites. Since the amount of traffics using Namsan 1st tunnel is greater than that of traffics using Namsan 3rd tunnel, many drivers using Namsan 1st tunnel must have moved to Namsan 3rd tunnel instead of shifting their driving time after the tolled period.

〈Table 11〉 : Traffic Changes before/after the toll start in 3rd Tunnel

	Vehicle Trips(Thursday)								
	before	1st week	change (%)	2nd week	change (%)	3rd week	change (%)	4th week	change (%)
morning	1,975	3,171	+60.5	3,076	+55.7	2,761	+39.8	2,969	+50.3
night	2,538	4,584	+80.6	3,391	+33.6	3,921	+54.4	4,189	+65.0

5.3. Route Change Impacts: Traffic situation in alternative routes

It was expected by levying congestion tolls on Namsan 1,3 tunnels that alternative routes to these tunnels would be more congested by vehicles shifted to escape tolls. There are four alternative routes as shown in Figure 2: Hangang-Ro, Sowol-kil(Namsan Circular Road), Jangchungdan-Kil, Namsan 2nd Tunnel.

Table 12 summarizes the changes of passenger car trips in the four alternative routes. The aggregate passenger vehicle trips in these routes increased from 13,059 to 13,747 (+5.3%) in the first week, to 14,022 (+7.3%) in the 2nd. The trend continued in the 3rd and 4th week. The vehicle trips recorded 13,790 (+5.6%) in the third, and 13,912 (+6.5%) in the fourth.. The most dramatic increase occured in Sowall-Kill, to which both 1 and 3 tunnels are closest..

〈Table 12〉 Traffic Volume Changes in Alternative Routes

	average traffic volume per hour								
	before	1st week	change (%)	2nd week	change (%)	3rd week	change (%)	4th week	change (%)
total	13,059	13,747	+5.3	14,022	+7.3	13,790	+5.6	13,912	+6.5
Sowal	2,958	3,427	+15.9	3,557	+20.3	3,619	+22.3	3,448	+16.6
Janchung	2,335	2,378	+1.8	2,531	+8.4	2,388	+2.3	2,495	+6.9
2nd tunnel	1,338	1,322	-1.2	1,437	+7.4	1,321	-1.3	1,374	+2.7
Hangang	6,428	6,620	+3.0	6,497	+1.1	6,462	+0.5	6,595	+2.6

The traffic speed changes appear on Table 13. Ironically, it was found to be improved in spite of the traffic volume increases in the routes. In the first week, the average speed in alternative routes was 31.8km/h, 30% improvement from previous 24.5km/h. The second week experienced 30.6km/h which is 24.9% improvement.

However, the speed decreased very quickly because, as shown in Table 10, the vehicle trips increased.. In the fourth week, the speed improvement reached to only 11.8%, from 24.5km/h to 27.4km/h.

〈Table 13〉 Traffic Speed Changes in Alternative Routes

	Ave. Travel Speed (Weeday Average, km/h)								
	before	1st week	change (%)	2nd week	change (%)	3rd week	change (%)	4th week	change (%)
total	24.5	31.8	+29.8	30.6	+24.9	29.6	+20.8	27.4	+11.8
Sowal	37.8	40.9	+8.2	38.7	+2.3	41.4	+9.5	41.2	+9.0
Janchung	22.1	26.6	+20.4	25.2	+14.0	23.1	+4.5	21.3	-3.6
2nd tunnel	20.8	36.9	+77.4	35.3	+69.7	32.0	+53.8	27.3	+31.3
Hangang	17.3	22.7	+31.2	23.0	+32.9	21.8	+26.0	19.7	+13.9

The speed improvement in spite of the traffic volume increase is maily due to the fact that major intersections of the alternative routes are mostly located near the CBD area, and the queue formed at these intersections reduced significantly due to the traffic reduction in the CBD area after the congestion pricing. In urban network, overall traffic conditions of a traffic corridor is highly dependent on the level of congestion at major intersections on the corridor. Also, the speed improvement are related with the strong enforcement of illegal on-street parking on the alternative routes.

5.4. Network Impact: Traffic Volume Changes in the Network

Table 14 shows the aggregate changes of vehicle trips in the network including Namsan 1,3 tunnels and 4 alternative routes. During the tolled time period, there were previously 273,230 vehicle trips in aggregate, consisting of 90,404 vehicle trips in Namsan 1,3 tunnels and 182,826 vehicle trips in the alternative routes. One month later, in Namsan 1,3 tunnels were 22,492 vehicles reduced, while in alternative routes 11,083 vehicles were added. In aggregate, the total 11,409 vehicles were disappeared in this network. This amounts to 4.2% of the total vehicle trips in the network. This result confirms that the effects of congestion charge in Namsan 1,3 tunnel are not offset by the worsening traffic congestion in alternative routes.

〈Table 14〉 Aggregate Traffic Volume Changes

	Namsan 1,3 tunnel			alternative route			total
	in	out	total	in	out	total	total
before	47,768	42,636	90,404	79,618	103,208	182,826	273,230
after	36,219	31,693	67,912	89,250	104,659	193,909	261,821
change	-11,549	-10,943	-22,492	9,632	1,451	11,083	-11,409
change rate(%)	-24.2	-25.7	-24.9	12.1	1.4	+6.1	-4.2

5.5. Mode Shift Impacts: Ridership Changes of Alternative Modes

1). Subway Ridership

Table 15 shows the changes of subway ridership during the weekdays after the Namsan 1,3 tunnel congestion pricing scheme began. The number of users of subway line #2 & #3 serving the CBD area has increased 2.3% in daily average. In specific, while the passenger ridership in subway 2 line (circular line) increased 2.6%, the ridership in subway 3 line (southeast to northwest line) increased only 1.4%.

〈Table 15> Changes of Subway Ridership

	Subway Ridership Change (1,000 people)											
	Average		Mon		Tue		Wed		Thur		Fri	
	before	after (chg,%)	11/4	11/11 (chg,%)	11/5	11/12 (chg,%)	11/6	11/13 (chg,%)	11/7	11/14 (chg,%)	11/8	11/15 (chg,%)
total	2,044	2,090 (+2.3)	2,173	2,292 (+5.5)	2,013	2,101 (+4.4)	2,014	2,026 (+0.6)	1,976	2,004 (+1.4)	2,041	2,026 (-0.7)
Line 2	1,478	1,516 (+2.6)	1,541	1,656 (+7.5)	1,467	1,527 (+4.1)	1,461	1,476 (+1.0)	1,444	1,457 (+0.9)	1,475	1,464 (-0.7)
Line 3	566	574 (+1.4)	632	636 (+0.6)	546	574 (+5.1)	553	550 (-0.5)	532	547 (+2.8)	566	562 (-0.7)

Seeing the daily variations of ridership, the increase was very apparent on Monday and Thueday, but on Friday the ridership decreased to a small extent. Overall, the rate of increase was quickly reducing as days go by. It is likely that the new subway users experienced inconvence and time loss of using subway, and that they must have shifted to the other alternatives such as bus or carpool.

2). Bus Ridership

Table 16 shows the bus ridership changes in Namsan 1,3 tunnel corridors.. There are only three bus lines on Namsan 1st tunnel, while ten bus lines on Namsan 3rd tunnel. The number of bus passengers passing Namsan 1,3 tunnels increased about

4,000, average 3.6% increase during week days and 6% increase for Saturday. To put it concretely, the rate of increase in Namsan 1st tunnel corridor was 1.3%, while the rate in Namsan 3rd tunnel was 4.2%, more than three time as much as in Namsan 1st tunnel. The difference may be caused by the differece of bus service level between these two corridors.. In addition, the traffic situation in the 1st tunnel was much worse than in 3rd tunnel because there had been a overbridge construction going on near the northern part of the 1st tunnel exit. Similar to the subway case, the rate of increase in the bus ridership is decreasing slightly as days go by.

<Table 16> Changes of Bus Ridership

	Bus Ridership Changes (1,000)													
	daily average		Mon		Tue		Wed		Thur		Fri		Sat	
	before	after (change,%)	11/4	11/11 (change,%)	11/5	11/12 (change,%)	11/6	11/13 (change,%)	11/7	11/14 (change,%)	11/8	11/15 (change,%)	11/9	11/16 (change,%)
total	109.9	113.9 (+3.6)	107.2	115.2 (+7.5)	110.3	118.9 (+7.8)	111.5	111.2 (-0.3)	109.3	110.7 (+1.2)	111.3	113.5 (+2.0)	100.0	106.1 (+6.1)
1st tunnel corridor	22.4	22.7 (+1.3)	21.8	22.0 (+0.8)	22.5	23.6 (+4.7)	22.9	22.9 (+0.0)	21.9	22.1 (+0.7)	22.8	22.9 (+0.2)	20.0	20.9 (+4.5)
3rd tunnel corridor	87.5	91.2 (+4.2)	85.4	93.2 (+9.3)	87.8	95.3 (+8.6)	88.6	88.3 (-0.4)	87.4	88.6 (+1.4)	88.5	90.6 (+2.5)	80.0	85.2 (+6.5)

3). Carpool

As can be seen from Table 17, the carpools with over 3 more passengers showed the most dramatic increase among the alternative travel modes. According to the field survey conducted during the morning peak (07:00 - 09:00), they increased from 2,198 to 5,648 vehicles (157% increase) in total. These results are very encouraging and reveal a promising characteristics of congestion pricing scheme. That is, CP has a very strong effect on the increase of carpools.

〈Table 17〉 Carpool Changes in Namsan 1,3 Tunnel

	before (11/7)	3 more carpool(veh)			reference
		after	change	change (%)	
total	2,198	5,648	3,450	157	both direction
1st tunnel	950	2,299	1,349	142	
3rd tunnel	1,248	3,350	2,102	168	

6. SUMMARY & CONCLUSION

The results of one month-long implementation show that in the fourth week, the traffic volumes in Namsan 1 and 3 tunnel dropped 24.2% and 25.4% than before, respectively, and the average vehicle speed in Namsan 1st tunnel increased from 25.3km/h to 35.7km/h, and in Namsan 3rd tunnel from 17.8km/h to 31.5km/h, and the share of untolled vehicles increased from 32% to 58%.

In the fourth week, the one hour traffic volume in Namsan 1 tunnel decreased 7.7% just before the toll levied and increased 37.8% one hour after, and in Namsan 3 tunnel increased 50.3% in one hour before and increased 65% in one hour after.

The number of passenger cars and corridor speed in 4 alternative routes increased 6.5% and 11.8% on average, respectively, total traffic volumes in a road network including Namsan 1,3 tunnel and alternative routes together dropped 4.2.

Finally, number of subway users has increased 2.3% in daily average, and bus passengers on Namsan 1,3 tunnels increased 3.6% during week days and 6% for Saturday. The carpools showed the most dramatic increase from 2,198 to 5,648 vehicles (157% increase)

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According to the results disclosed thus far, the congestion pricing in Namsan 1,3 tunnel is viewed as the most successful TDM measure conducted in Seoul in terms of alleviating CBD congestion. Therefore, the authors recommend that congestion pricing scheme should be extended to the other major congested arterials, and that, for responding to the equity issues related with congestion pricing, all the revenues collected be invested for improving the service quality of mass-transit systems.

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