EFFECTS OF CONGESTION PRICING AT THE NAMSAN TUNNELS IN SEOUL

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Abstract: The purpose of this paper is to evaluate the effectiveness of Congestion Pricing scheme in Namsan #1 and #3 tunnels in downtown Seoul after two years of its implementation. The effectiveness of the scheme was measured by the changes of various traffic impacts. On the average of two years, the traffic volume in the two tunnels was reduced by 10.6% and the speed increased by 47.7%. The average travel speed on four alternative routes was increased 10.6%, while the traffic volume of alternative routes was increased. Furthermore, the number of carpools with more than 3 occupant persons during the peak periods was increased by 145%. The results from two-year-long implementation of the congestion pricing show a sizeable reduction of traffic volumes and increases in average travel speed in the tolled links. From the viewpoint of roadway network, the congestion pricing scheme has improved traffic conditions overall in Seoul Metropolitan Area, especially in the CBD.

1. INTRODUCTION

Seoul has been known for the notoriety of its severe traffic congestion. In order to mitigate the congestion problem, the transportation policy of Seoul Metropolitan Government (SMG) had been mainly focused on the supply of transportation systems such as constructing new urban freeway and subway lines until the early 1990's. However, after the year of 1993, the SMG has approached the traffic problems from a different view considering the limitation of the transportation policy to solve the traffic congestion problem by the supply of transportation systems. The approach is to manage the demand of transportation systems by the implementation of congestion pricing scheme.

Congestion Pricing scheme is generally considered to be the most effective scheme to control auto-uses, as well as to reflect location and time variations of traffic congestion among many transportation demand management (TDM) techniques. However, the scheme was not a popular alternative. Very few cities adopted congestion pricing scheme, although it was considered in many major cities in the world. For an example, Singapore experienced a sizable success relieving traffic congestion through Area License Scheme (ALS) in CBD.

The purpose of this paper is to evaluate the effectiveness of congestion pricing scheme in Namsan #1 and #3 tunnels in downtown Seoul after two year of its implementation. The SMG will decide the expansion of congestion tolled sites based on the results of the Namsan Tunnels. The paper consists of five parts. They include 1) background of implementing congestion pricing scheme 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 was measured by the changes of the followings; 1) traffic volume and average speed of Namsan #1 and #3 tunnel corridors, 2) traffic volume of right after and before the time period of congestion fee charged, 3) traffic volume and average speed of four alternative routes, 4) total traffic volumes in a network consisted of Namsan #1 and #3 tunnels and four alternative routes, and 5) mode changes.

2. BACKGROUND OF IMPLEMENTING CP IN SEOUL

The current roadway network in Seoul is quite insufficient to carry massive amount of traffic volumes. The paved road ratio in Seoul is only 20.4%, which is somewhat lower than the major cities in other countries. In 1996, the total length of urban freeways is 135 km out of the total length of the paved road, which is 7,689 km, in Seoul (see Figure 1).

(Figure 1) Arterial Roadways in Seoul

Most of arterial roads in Seoul are heavily congested throughout a day. It is, however, financially infeasible to build new roadways to the extent that mitigates the traffic congestion in Seoul, because of insufficient land supply and high land prices. It is noteworthy that about 35% of the CBD workers use auto vehicles for their commuting, and that other workers use public transit due to either traffic congestion or the shortage of parking spaces (SMG, 1994a). It implies that there is plenty of latent demand of auto vehicles waiting for the chance of driving auto vehicles when the traffic conditions are improved. Considering this respect, it is hopeless to expect that the traffic congestion can be relieved only by road construction.

The number of daily trips increased over four times from 1970 to 1995 (See Table 1). It jumped from 5.7 million in 1970 to 27.1 million in 1995. The number has been increasing steadily due to continuing growth of the car-ownership and the number of commuters traveled long distance from satellite cities. Furthermore, the average number of daily person trips increased from 2.29 trips/day in 1990 to 2.62 trips/day in 1997. It should be noted that the average household income in Seoul increased almost three times during the period between 1985 and 1995.

(Table 1) The trends of daily trips

	1970	1980	1990	1995	1996	1997
Daily trips (×1,000)	5,750	12,600	24,638	27,099	27,762	27,203

Source: Seoul Metropolitan Government, 1998d

Table 2 summarized some important results for the share of travel modes in Seoul which was obtained from the O-D survey conducted by Seoul Development Institute in 1996. Until 1996, bus was the most predominant travel mode in Seoul. In 1997, however, the subway carried 30.8% of all the daily trips occurring in Seoul and it has become, for the first time, the most predominant travel mode (see Table 2). It can be seen from Table 2 that the share of bus mode was remarkably decreased from 1980 to 1997 due to the effect of heavy investment on subway construction. However, the share of auto vehicle mode was sharply increased in the year of 1995 and the share was maintained at more or less 20 %. It seems that the bus ridership is very sensitive to the implement of subway network, but the auto ridership is not much dependent upon the level of subway service.

(Table 2) Percent of Daily Trips by Travel Modes

	1980	1985	1990	1995	1996	1997
Bus	66.0	58.0	43.3	36.7	30.1	29.5
Subway	7.0	14.0	18.8	29.8	29.4	30.8
Taxi	19.0	16.5	12.8	10.7	10.4	10.1
Others (Passenger Cars)	8.0 (NA)	12.5 (NA)	25.1 (14.0)	22.8 (14.5)	30.1 (21.1)	29.7 (20.6)

Source: Seoul Metropolitan Government, 1998d

Note: In the case of subway mode, a transfer among different subway lines was counted as an independent trip.

Traffic conditions in Seoul were normal without a serious congestion problem up to the early 1980s, except during the period of rush hours. The traffic patterns changed from rush-hour peaks to all-day peaks in the end of 1980s. The overall traffic speed on major arterial roads in Seoul kept declined until 1996 and started to bounce back from 1997 (see Table 3). This trend has been resulted from significant changes of traffic environment in Seoul. First, the economy has started sliding down in 1997 caused by IMF economic crisis and of about 30% increase of oil price as of December 1997 (SMG 1998b). Secondly, passenger vehicle drivers using Namsan #1 and #3 tunnels linked to the CBD have been charged 2,000 won (US $1.8) congestion fee since the late 1996.

(Table 3) The Trend of Travel Speed Changes in Seoul

(unit : km/h)

		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Auto	All	32.6	24.2	24.6	22.6	23.5	23.2	21.7	20.1	21.1	25.4
	CBD	18.7	16.4	17.7	19.3	20.0	20.0	18.3	16.4	16.9	17.7
	other	37.2	25.8	21.9	22.9	23.8	23.4	21.9	21.2	21.3	25.9
Bus		18.6	18.8	18.2	16.9	17.0	18.4	18.8	18.4	18.7	20.1

Source: Seoul Metropolitan Government, 1997b, 1998b, 1998c

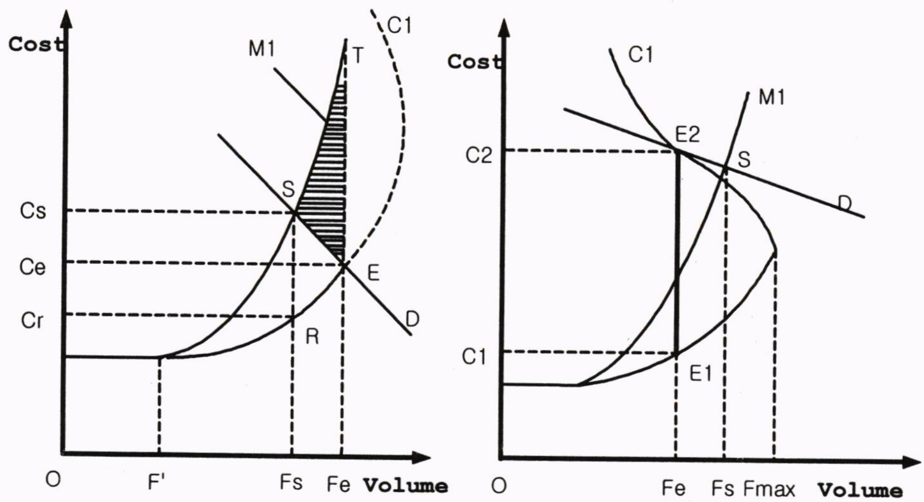
3. CONTENTS OF NAMSAN TUNNEL CONGESTION PRICING SCHEME

The SMG started charging, from November 11 (Monday), 1996, 2,000 won (US $2.2) congestion tolls for 1 and 2 (including driver) occupant private auto-vehicles using Namsan #1 and #3 tunnels, major arterial roads linking the southern part of Han-river with the old downtown. The two corridors were notorious for excessive private auto vehicle uses. The private autos consisted of 90% of total traffic volume, which was the highest among all the corridors linked to CBD, and single passenger autos account for 78% among the private auto vehicles. Toll booth facilities for cash collection have existed in Namsan #1 and #3 tunnels, where 100 won tolls were collected for 20 years until October 1996 to recover the construction costs. 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 weekday, 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 (five times of a congestion fee). All the private auto-vehicles with 1 and 2 passengers (including driver) have to pay tolls for using tunnels. However, following vehicles are exempted from charge: 3 or more passenger occupant private car, taxi, all kinds of buses, vans, trucks, diplomats' vehicle, reporter's vehicle, government vehicles, ceremony vehicles.

4. ANALYSIS FRAMEWORK

The main purpose of the congestion pricing is to relieve traffic congestion by reducing vehicle volumes on congested roadways. Congestion pricing plays a role of reducing social costs by switching the condition of a roadway network equilibrium from user optimum to system optimum. In theory, see the left hand side of Figure 2, where the demand curve D meets the marginal cost curve M1 in a forward bending section, it should be verified that traffic volumes decrease from Fe to Fs while traffic speed improves on the corridor where the charge is levied. Where the demand curve crosses with the marginal cost curve in a backward bending section (see the right hand side of Figure 2), it can be expected that the traffic volume increases from Fe to Fs and speed increases below C2 (Small, 1983).



(Figure 2) The theory of congestion pricing

In general, congestion tolls are imposed when congestion occurs.. Accordingly, tolls are collected in a limited time base, and vehicles tend to concentrate on the time period just before and after the congestion charging period to escape the toll. It is desirable if traffic volumes during the peak periods decrease when 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 and #3 tunnels have several alternative routes, the congestion toll may worsen traffic situation in those routes. In which case, the pricing only plays a role of shifting the congestion without improving traffic conditions in a network. Therefore, for validating the effectiveness of the scheme, it is necessary to check the changes of traffic situation in those alternative routes, as well as the relevant network.

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. 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 congestion pricing scheme at the Namsan #1 and #3 tunnels 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 and the composition of the vehicles passed the two tunnels

2) time shift impacts: traffic volume of just before and after congestion tolls in Namsan #1 and #3 tunnels
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 the relevant network

5. ANALYSIS RESULTS

5-1. Trip Reduction Impacts on Namsan #1and #3 Tunnels

1) The Impacts of Congestion Pricing

It has been two years since Namsan #1 and #3 tunnel congestion pricing scheme started in November 1996. Two year long results of traffic monitoring show that it contributed to improve the traffic situation on the corridors to a significant level. During the peak periods, the number of passenger vehicles has reduced 34.2%, and the average link travel speed on these corridors increased from 21.6 km/h to 31.9 km/h in two years (see Table 4). The survey on the drivers passed Namsan #1 and #3 tunnels shows that 93% of the respondents use the tunnels because of the fast speeds.

However, comparing traffic volume changes for two years, we found that the reduction rates are continuously declining, except the period of June 1998, from -24.9% in one month after to -10.6% in two years. The short recovery during the first half of 1998 is closely related with IMF economic crisis starting December 1997.

(Table 4) Traffic volume and speed changes on Namsan Tunnel corridors

Classification	Before	1996.12	1997.6	1997.11	1998.6	1998.11
Traffic volume (vehicle)	90,404	67,912 (-24.9%)	77,377 (-14,4%)	78,078 (-13.6%)	76,878 (-15.0%)	80,784 (-10.6%)
Speed(km/h)	21.6	33.6 (+55.6%)	35.5 (+64.8%)	29.8 (+38.0%)	44.8 (+107.4%)	31.9 (+47.7)

2) The Combined Impacts of Congestion Pricing and Oil Price Increase

The gasoline prices have fluctuated continuously since November, 1997 because of foreign currency crisis and oil tax increase,. Notwithstanding the instability of gasoline prices, the number of vehicles using Namsan #1 and #3 tunnels kept increasing during the period. It was caused by continuous increase of toll-free vehicles, while tolled vehicles have declined slightly in their number. Comparing the tolled auto volumes in September, 1998 with those in November, 1997 when the gasoline prices were relatively stable, the former is 7% as low as the latter (see Table 5). It seems that auto users are very sensitive to the change of the gasoline price.

(Table 5) Traffic volume changes resulting from oil price variation

Date		96.11	97.11	98.1	98.2	98.5	98.9
Gasoline Price (won per liter)		638	839	1143	1190	1041	1224
Namsan #1 and #3 tunnels	Volume in charged time period	90,404	78,078 (- 13.6%)	74,017 (-18.1%)	75,592 (- 16.4%)	78,220 (- 13.5%)	80,630 (-10.8%)
	Toll Free Auto volume	23,526	47,482 (101.8%)	49,941 (112.2%)	51,912 (120.7%)	52,619 (123.7%)	54,396 (131.2%)
	Charged auto volume	66,878	30,596 (-54.3%)	24,076 (-64.0%)	23,680 (-64.6%)	25,601 (-61.7%)	26,234 (-60.8%)

3) The Impacts of Temporary Suspension of Congestion Pricing

In the early August 1998, heavy rainfalls swept major streets in Seoul, and many of them have been shut down for a few days. The congestion charging at the Namsan #1 and #3 tunnels was suspended for 8 days until the restoration works were over. The traffic monitoring by Seoul Metropolitan Government on these tunnel sites shows that the traffic situation on the Namsan #1 tunnel quickly returned to the situation before the congestion pricing had been implemented (see Table 6). The traffic volumes passed the Namsan #1 tunnel were greater than the previous one in the first day of suspension. However, the traffic volumes passed the Namsan #3 tunnel were less than traffic volume observed before the congestion pricing implemented. The main reason for this can be explained as follows. The Namsan #3 tunnel is connected with Banpo Bridge and Jamsu Bridge which is underneath the Banpo Bridge. During the heavy rainfalls, the Jamsu Bridge came below the water level, so the bridge had been shut down. Thus, the traffic volume traveled the Namsan #3 tunnel corridor was decreased much less than the traffic volume observed before the congestion pricing implemented.

In summary, it can be seen from table 6 that the traffic volumes at the two tunnel sites have been gradually increased. This finding support the argument that the congestion pricing has played a key role in alleviating traffic congestion in CBD.

(Table 6) Daily traveling volume changes after the temporary suspension

Classification	Before Congestion Pricing	8/6 (Thu)	8/7일 (Fri)	8/10 (Mon)	8/11 (Thu)	8/12 (Wed)	8/13 (Thu)
Total	90,404	75,365 (-16.6%)	77,684 (-14.1%)	78,462 (-13.2%)	83,595 (-7.5%)	83,966 (-7.1%)	86,516 (-4.3%)
Namsan #1 Tunnel	39,982	40,547 (1.4%)	40,303 (0.8%)	40,467 (1.2%)	43,917 (9.8%)	44,002 (10.1%)	43,324 (8.4%)
Namsan #3 Tunnel	50,422	34,818 (-30.9%)	37,881 (-24.9%)	37,995 (-24.6%)	39,678 (-21.3%)	39,964 (-20.7%)	43,192 (-14.3%)

5-2. Time Shift Impacts

The monitoring result shows that the congestion pricing helped relieve traffic congestion on Namsan #1 and #3 tunnel corridors by affecting travel time-shifting behavior. Before the toll started in 1996, the traffic volume between 06:00 and 07:00 was 5,159 (see Table 7). The traffic volume has increased by 12.7% after two years.

As expected, auto drivers changed their departure time and the time-shift traffic volume was peaked in June 1997. The time-shift traffic pattern between 21:00 and 22:00 is similar to the pattern between 06:00 and 07:00. However, the traffic volume change between 21:00 and 22:00 are much bigger than the morning time period with the exception of June 1997. It was due to the fact that the office hours in Korea are very flexible while the opening hours are very strict.

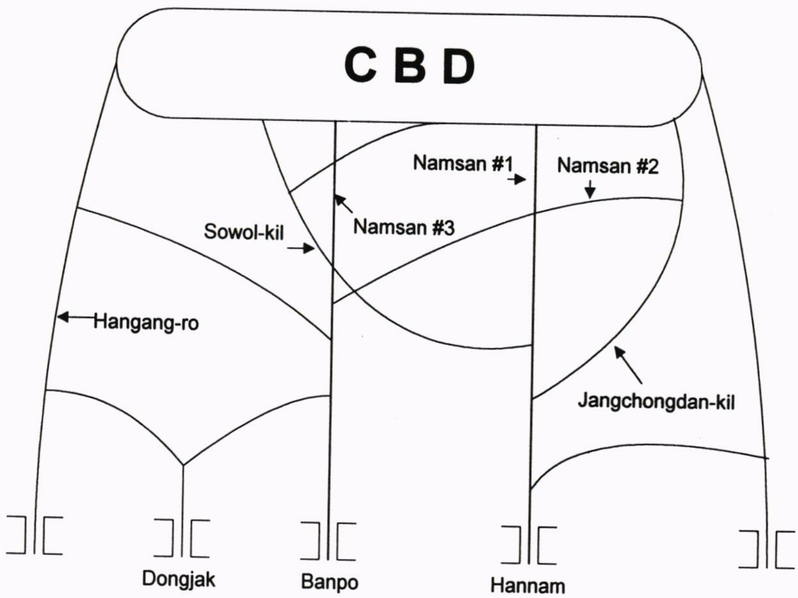
(Table 7) The traffic volume changes just before and after

Classification	Before	1996.12	1997.6	1997.11	1998.6	1998.11
Just before (06:00~07:00)	5,159	5,773 (+11.9%)	6,411 (+24.2%)	6,472 (+22.5%)	6,010 (+16.5%)	5,812 (+12.7%)
Just after (21:00~22:00)	5,369	7,136 (+32.9%)	6,525 (+21.5%)	6,581 (+22.6%)	7,032 (+31.0%)	7,806 (+45.4%)

5-3 Route Change Impacts

For checking the traffic situation of alternative routes, four routes which are close to the Namsan #1 and #3 tunnels and are linked to the CBD were selected. These are Hangang-Ro, Sowol-kil, Jangchoongdan-kil, and Namsan #2 tunnel (see Figure 3). For the traffic volume survey, only private passenger vehicles were counted, since other type vehicles would hardly change their routes for escaping tolls. The survey period is from 06:00 to 22:00.

It was expected that the alternative routes would be severely congested because of route changing vehicles to escape the congestion toll. The expectation was correct in one way, but not in the other day. While the traffic volumes on these routes have increased up to 15%, the average traffic speeds on them have increased as well (see Table 8). The speed improvement can be explained as follows. First, overall traffic conditions on corridor in an urban network is highly dependent on the level of congestion at major intersections and the traffic queues formed at the major signal intersections linked to Namsan corridors reduced significantly due to the reduction of traffic volumes after congestion charging. Secondly, strong enforcement of illegal on-street parking in the alternative routes must have reduced traffic disturbances.



(Figure 3) Roadway Network near Namsan #1and #3 Tunnels

(Table 8) Traffic volumes and speed changes on Alternative routes.

Classification	Before	1996.12	1997.6	1997.11	1998.6	1998.11
Traffic volume(vehicle)	13,059	13,912 (+6.5%)	15,016 (+15.0%)	13,606 (+4.2%)	14,367 (+10.0%)	14,491 (+11.0%)
Speed(km/h)	24.5	27.4 (+11.8%)	28.5 (+16.3%)	30.0 (+22.4%)	33.8 (+38.0%)	27.1 (+10.6%)

5-4. Mode Shift Impacts

While passenger vehicles with less than 2 occupant persons have been reduced in their number, toll-free vehicles such as bus, taxi, and more than 3 occupant passenger carpools have drastically increased. The increasing trend of these vehicles is very consistent during the two year period from 55.3% in December, 1996 to 118.9% in November, 1998. Since its inception, taxi has recorded the most drastic increase, 211.6%, followed by carpools 144.9% (see Table 9).

(Table 9) Traffic volume changes of toll-free vehicles (07:00～09:00, 17:00～19:00)

	Before	1996.12	1997.6	1997.11	1998.6	1998.11
Total	6,181	9,600 (+55.3%)	11,183 (+80.9%)	11,488 (+85.9%)	12,494 (+102.1%)	13,534 (+118.9%)
Car-pool	1,057	2,792 (+164.1%)	2,404 (+127.4%)	2,598 (+19.9%)	2,426 (+129.5%)	2,589 (+144.9%)
Bus	792	825 (+4.2%)	1,045 (+31.9%)	1,148 (+44.9%)	1,367 (+72.6%)	1,285 (+62.2%)
Taxi	1,848	2,938 (+59.0%)	4,173 (+125.8%)	4,178 (+126.1%)	4,798 (+159.6%)	5,759 (+211.6%)
Truck etc.	2,484	3,045 (+22.6%)	3,561 (+43.4%)	3,564 (+43.5%)	3,903 (+57.1%)	3,901 (+57.0%)

5-5. Network Impact

Table 10 shows the network impact of congestion pricing based on route speeds (refer to Figure 4). The ① and ② routes in the middle of which Namsan congestion pricing sites are located experienced three time as much speed increases compared with the average of all the radial type roads in Seoul. As the same token, ③ and ④ routes next to ① and ② routes recorded 42% and 50% speed improvement, which are almost doubled of all the radial type roads. In the CBD, all the arterial roads except ⑨ have experienced a sizable speed improvement. It can be concluded from the results that congestion pricing can improve roadway conditions in a large scale traffic network if the sites are well selected.

(Figure 4) A roadway network including Namsan #1 and # 3 tunnels

(Table 10) The speed changes of adjacent routes

Link type	Link	1996	1997 (The changing rate of 1996)	1998 (The changing rate of 1996)
Radial type	① Hotel Seajong ~ Yang-gae I.C	22.1	24.4(10.4%)	26.5(19.8%)
	② Hoi-hyen ~ The great Holl of Art	17.0	25.3(49.2%)	28.1(65.7%)
	③ Chungmooro 5ga Dogokdong	17.5	14.6(-16.5)	24.8(42.0%)
	④ Seoul Station ~ Namtaeryoung	17.2	23.4(36.1%)	25.9(50.3%)
	Average of all the Radiation roads	19.3	20.6(6.5%)	24.5(26.8%)
Urban freeway type	⑤ Hangju Bridge ~ Ha-ildong I.C	40.2	46.5(15.7%)	53.7(33.8%)
	Average of all the urban highways	33.1	38.1(14.9%)	44.2(33.5%)
Grid type	⑥ Hotel Hilten ~ Goang-hidong	40.3	31.5(-21.7%)	27.8(-31.1%)
	Average of all the grid road	19.8	19.8(0.0%)	22.6(14.3%)
Arterial road in CBD	⑦ Seoul Station ~ Goang-hi Station	14.7	17.7(20.1%)	21.5(45.9%)
	⑧ Seosomun ~ Dongdaemun	12.3	17.3(40.1%)	20.9(69.3%)
	⑨ Dong-a ilbo ~ Chuong-gea 6 ga	19.8	16.4(-17.4%)	20.9(5.6%)
	⑩ Goangwhamun ~ Seoul Station	18.9	25.3(33.8%)	23.0(21.5%)
	⑪ Angukdong ~ Hoi-hyendong	14.9	17.4(16.8%)	21.6(45.1%)
	Average of all the arterial road in CBD	16.4	16.9(2.5%)	17.7(7.8%)

Data source : 1996, 1997, 1998 Annual travel speed survey in Seoul, Seoul Metropolitan Government

6. CONCLUSION

The results from two year-long implementation of congestion pricing at Namsan #1 and #3 tunnels show a sizeable reduction of traffic volumes and increases in average travel speed in the tolled links. In two year, the traffic volume in Namsan #1 and #3 tunnels has been reduced by 10.6% and the speed increased by 47.7% due to the congestion pricing scheme, while the average speed on the alternative routes increased 10.6% in spite of 11% traffic volume increase. Furthermore, the number of carpools with more than 3 occupant persons during the peak periods increased by 145%. From the viewpoint of roadway network, the congestion pricing scheme improved traffic conditions overall in Seoul Metropolitan Area, especially in the CBD. The results show that the congestion pricing in Namsan #1 and #3 tunnels is viewed as a successful TDM application conducted in Seoul in terms of alleviating congestion-ridden links. Therefore, we recommend that the CP should be extended to other major congested links.

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