

## THE ESTIMATION OF DIVERTED TRAFFIC VOLUME BY TOLL APPROPRIATION

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**abstract:** The objective of the paper is to analyze diverted traffic volume by the changes of the toll charge in the base of the paper which will be conducted by establishing simulation model and evaluating its appropriateness based on the various toll charges on the Second Urban Expressway built recently in Pusan Metropolitan. Therefore, this paper searches the road traffic problems of Pusan and the needs for toll road through various materials and observes the side effects and problems of the present toll policy. In result, I intend to establish the characteristics and future direction for charging the toll of the expressway by means of this paper.

### 1. INTRODUCTION

The traffic demand of metropolitan area has a character of passing far over the supply capacity in social and economic development, especially in terms of demand for road use. The demand is increasing day after day as vehicle service becomes more popular by private cars. To catch up with the increasing traffic demand and keep supply to the level of the demand, the optimization of the existing traffic facilities by TSM should be considered.

Among investment on new traffic facilities, long construction period and high investment on roads impose high burdens for building more roads and in reality, lead to the impossibility of their construction, under the insufficient government finances and its support. More privatization on investment of traffic facilities is required to compensate the present insufficient facilities and their improvement. The original intension of privatization on traffic facilities has been concocted to reimburse the construction expenses, which has made users pay extra toll charge as well as taxes during the reimbursement period for it. When suppliers and users(demanders) reach a certain agreement on the degree of toll charge, the users' burden for traffic facilities decreases, which could eventually lead to the increased usage and consequently to the prompt reimbursement of construction expenses. The originally intended traffic function to solve traffic congestion by toll road will work and be prosperous.

Therefore, the purpose of this study is to analyze diverted traffic volume by the changes of the toll charge, which will be conducted by establishing simulation modeling and evaluating its appropriateness based on the various toll charges on the Second Urban Expressway built most recently.

This study searches the road traffic problems of Pusan city and the needs for toll road through various materials and observes the side effects and problems of the present toll fee policy. The Pusan second Urban Expressway has been used as the study scope for diverted

traffic volume. The first section of the Pusan second Urban Expressway, 8.1 Km was built up in Dec. 8. 1992 and has been tolled from Oct. 15. 1993. The traffic survey was conducted by traffic inflows on modal split (the kinds of vehicles) and inflow ramps. The first survey was conducted during the rush hours between the period of 7 to 10 AM and that of 17 to 20 PM in September 23. 1993 when the toll was not charged and the second on the same time basis in June 6. 1994 when the toll was charged. Diverted rate Formula (Model) by AASHO (American Association of State Highway Officials) was systemized to calculate diverted traffic volume on the different toll charge basis, which was used to analyze diverted traffic volume and limitation of the toll charge.

## 2. THE TRANSPORTATION CONDITION OF PUSAN METROPOLITAN AND NECESSITY OF THE TOLL WAY

### 2.1 The Present Status and The Problem of The Road Transportation

#### A. The increment of traffic demand

The automobile volume of Pusan city has increased from 62,419 cars in 1980 to 469,622 cars now in Dec. 1993, rising up to by about 16.8% each year for 10 years. Based on modal split, the volume of private cars has been rapidly increased due to the increment of personal income and development of automobile industry. The modal split of private cars has been up 61.0% in 1993 since 35.9% in 1985. Regarding the LOS level of downtown arterial road in 1993, Table 1 shows most roads have below the level F resulting in serious traffic congestion. Among them, the entire section on the Urban Expressway, the section on Somyon to Yangchong and vice versa, the section of Chungjang-Ro on the Customs to Munhyon-dong and vice versa show the F level with heavy traffic congestion.

Table 1. Service level of the arterial road in Pusan Metropolitan

Arterial Road Name	District per direction	Traffic Capacity (PCU/hour)	Peak time Traffic Volume (PCU/hour)	Traffic/Capacity (V/C)	Service Level
Urban Expressway (1)	Munhyon → Wondong	4,400	6,801	1.55	F
	Wondong → Munhyon	4,400	7,020	1.09	F
Urban Expressway (1)	Wondong → Kuso	4,400	4,793	1.09	F
	Kuso → Wondong	4,400	4,806	1.09	F
Jungang-Ro(1)	City Hall → Somyon	4,450	4,320	0.97	F
	Somyon → City Hall	4,450	44,093	0.99	F
Jungang-Ro(2)	Somyon → Yangchong	4,450	48,451	1.09	F
	Yangchong → Somyon	4,450	5,084	1.14	F
Jungang-Ro(3)	Yangchong → Kuso	4,450	3,851	0.87	D
	Kuso → Yangchong	4,450	3,757	0.84	D
Chungjang-Ro	Customs → Munhyon	4,450	55,171	1.24	F
	Munhyon → Customs	4,450	53,723	1.21	F
Suyong-Ro(1)	Munhyon → Namchon	3,350	4,616	1.38	F
	Namchon → Munhyon	3,350	4,885	1.46	F
Suyong-Ro(2)	Namchon → Suyong	2,250	3,281	0.98	F
	Suyong → Namchon	2,250	3,364	1.01	F
Kudok-Ro	Dukchon → Anlak	4,450	6,644	1.49	F
	Anlak → Dukchon	4,450	7,033	1.58	F
Kayo-Ro	Somyon → Chulae	3,350	68,917	2.05	F
	Chulae → Somyon	3,350	66,900	2.00	F

### B. The lack of road facilities

The road ratio of Pusan is 14.4% on Dec 31, 1993 lower than that of Seoul 19.3%, Daejun 22.4%, Incheon 16.5%, 15.6% and Kwangju 14.9% and has been increased by 2% only during the last five years. Furthermore, in terms of parking facilities necessary to solve parking problems, 34960 spaces are on-street parking, which is 20.8% out of total 168,099 spaces now on Dec.1993. It is also one of the factors disturbing traffic flow.

Table 2 shows the expected cargo quantity of goods transported on the public roads in Pusan Metropolitan. It shows the cargo quantity of goods in the city is expected to increase 1.8 times, from 231,764(ton /day) in 1991 to 419,512(ton/day) in 2011. Cargo quantity of in-and-out goods from other cities is expected to increase 1.8 and 2 times each from 166,975(ton/day), 151,844(ton/day) in 1991 to 308,494(ton/day), 302,089(ton/day) in 2011.

Therefore, ratio of cargo quantity of in-and-out goods out of total cargo quantity in Pusan is to be expected to increase to 57.3% in 2011 from 56.0% in 1991. This shows a lot more increase compared to that of 45.9% in 1983. The construction of ring roads should be more actively progressed to handle the in-and-out flows of freight traffic.

Table 2. The cargo quantity goods transported of the future public road in Pusan

Year	intercity		inflow		outflow		passing		Total	
	Quantity of goods transported	%	Quantity of goods transported	%	Quantity of goods transported	%	Quantity of goods transported	%	Quantity of goods transported	%
	(Unit : Ton/day)									
1983	147,847	50.2	68,537	23.3	66,488	22.6	11,496	3.9	294,467	100.0
1991	231,764	40.7	166,975	26.7	151,844	26.7	19,085	3.3	569,650	100.0
1996	273,675	40.2	193,644	27.8	189,868	27.8	24,764	3.6	681,950	100.0
2001	318,791	39.8	231,819	27.7	222,523	27.7	28,907	3.6	802,040	100.0
2006	368,631	39.8	265,370	28.7	257,968	27.9	33,310	3.6	925,279	100.0
2011	419,512	39.3	308,494	28.9	302,089	28.4	37,360	3.5	1,067,455	100.0

## 2.2 Needs and Realities of The Toll Road

### A. Needs for toll road

Roads have a character of the public goods (used by the public) so that they are built with taxes and supposed to be possessed by the government. However it is not easy to carry out all the construction with insufficient government finances. Privatization to supply better and more roads is needed and it will result in toll charge on toll road system. On this side, it is required to induce the toll road system to solve the investment problems in Pusan. Furthermore, it is necessary to utilize the toll road system to boost regional development and achieve a well-structured city (better city). The most effective way to utilize the toll road system is to find out optimization on the most appropriate toll charge level socially agreeable and to consider the better management systems in various ways.

### B. The realities of the toll roads

The initial toll road in Pusan city was established in 1977. Today's circumstances of toll road in Pusan is two Urban Expressways and 2 tunnels as the Table 3 shows.

The primary role of the first Urban Expressway is strongly recommended to meet the needs of urban expressway as means of managing cargos by sea, considering the character of Pusan's traffic volume in comprehensive ways.

Table 3. The present state of the toll roads in Pusan Metropolitan

(Unit : million won)

Road Name	Total length(m)	investment cost	the period of the toll	Traffic volume (per day)	Mark
The first Urban Express	15,700	560	1981. 4. - 1999. 5.	74,278	Pusan city
The second Urban Express	10,590	4,449	1993.10. - 2015.12.	65,048	Pusan city
Kudok Tunnel	1,870	469	1988. 6.- 2003.11.	63,344	Private Capital
The second Mandok Tunnel	1,740	448	1988. 6. - 2008. 5.	64,093	Private Capital

This road connecting the wharf area and nearby areas was originally supposed to reduce the traffic congestion by removing the through traffic of cargos from the inner city. The sources for total construction costs was made up by 52.4% from the State government's tax and 47.4% from the Federal government's tax. The facility controlled by the Control Department of Urban Expressway and the toll-imposed period is from Apr. 1. 1981 to May. 31. 1999. At present, the toll charge is 200 won for small sized vehicle and 400 won for big size vehicle from Munhyon to Wongdong and 200 won for small one, 400 won for big one entering from Wongdong.

The second Urban Expressway was built from 1988 to 1994. This road was supposed to solve the heavy traffic congestion on Gaya Street by expending East-West traffic roads, reduce traffic congestion of the inner-city and speed up the traveling time by providing ring roads for cargos by sea, and improve the efficiency of the existing roads by establishing the link roads between the urban expressway and Pusan-Masan Expressway. The monetary sources were supported by 59.1% of the Pusan government's tax, 40.8% of privatization, and 0.1% of the Federal government tax. The toll charge was unavoidable due to the private fund and maintenance costs. The Control Department of Urban Expressway is in charge of managing and maintaining the facilities and toll charge period is from Oct. 15 1993 to 2015.

In terms of tunnels, there are two, Guduk and the 2nd Manduk which are privately supported to build.

Guduk tunnel was started to construct in Apr. 4. 1981. and built up on July. 10. 1984. The toll charge is due to be imposed from Dec. 20. 1984. up to the completion of reimbursement expected by 2003. The tunnel accommodates the traffic inflow to the Pusan-Masan Expressway shortening the detour of the Nakdong and Gaya -Ro and contributing to the reduction of the traffic congestion in the CBD.

The 2nd Manduk tunnel was built to cope with the traffic congestion caused by the rapidly increased traffic volume on the 1st Manduk tunnel. The second one was begun to build on July 1. 1984. and open to the public on April. 11. 1988. It now provides us a better traffic condition such as the effective connection between the Kyongbu Expressway and the Namhae Expressway and contributes to the balanced development between Dongre-Gu (district) and Buk-Gu (district).

### 3. THE EXPECTED EFFECT OF THE TOLL POLICY AND THE ANALYSIS OF ITS PROBLEM

### 3.1 The Expected Effects of The Toll Policy

It has been asserted that the road-the-semi-public goods which does not have the two characteristics of the public goods, non-discrimination and non-competitiveness at the same time costs less than the road is not built from the society's perspective, when the society's loss is likely to occur because of the lowered demand by the imposed toll charge and the delay as the cars have to stop to pay the toll. Therefore, if toll is charged on the crowded areas, consumer's surplus will decrease. However, society's loss can be reduced because of improved traffic condition. Thus toll will keep a proper traffic volume from the social perspective.

#### A. Financial

Western Europe (especially Italy, Spain, and France) financed the construction of the local expressways through the toll and recently they had the private companies take part in the construction of the intercity high-speed roads to share the financial burden. For example, France had been building about 600 Kilometers of local expressways and there are six public-private and one private construction company. These companies solely depend on the toll from the consumers, drivers - they do not get any money from the government as far as the cost of construction and maintenance concerned. The government decides the amount of increase and the time considering the effect on the public and the financial condition of these companies. For example in Pusan, the 2nd City Highway, Kudok Tunnel and the 2nd Manduk Tunnel are maintained by the toll.

#### B. Improvement of traffic condition(A toll is a mean of traffic demand suppression)

Hochman(1992) says there is outer-negative economy in a city, and congestion and pollution are the main factors of the outer-negative economy of the traffic. He explains that the centralization of the employment and of the transit, are the cause and thus, asserts that the outer-negative economy can be reduced. The expected effects are, from the point of traffic management, first the time, the cost, and the inconvenience can be improved by the traffic control of the crowded areas. Second, by charging different amount of toll, car pool can be encouraged. Third mass transportation can improve the condition too - the service of it should be improved beforehand. In terms of environments, first air pollution and energy consumption can be decreased. Second the outlook of the city would get better. Third, vehicle noise can be reduced. In terms of economy, first, trip time can be shortened by less traffic volume. Thus, second, the cost of trip can be lowered too. In terms of administration, it would be possible to predict and estimate the demand of traffic. In other words, it would be possible to keep the volume of traffic at a certain level.

It is true that there are some negative side effects. For example, drastic decrease of traffic volume by heavy toll can be expected. At small amount of toll, drivers might not feel the burden. But if too heavy toll should be charged - or at least they feel that way - drivers might feel it unfair in terms of equal opportunity And the delay of traffic flow might be cause by stopping at toll gate and the cost of maintenance.

### 3.2 The Problems of Toll Roads

The toll roads, as they are mentioned above, are to promote private investments. Therefore it is definitely reasonable and important for the private companies to take the expected amount of traffic volume into consideration for the purpose of the reimbursement of the construction cost. The period of charging toll, in case of Japan, is scheduled to be 30

years to reimburse the invested cost. But in Pusan it is schedule to be 20 years and they have been imposing it - thus it is rather short amount of time to get the cost back, and 10 - 12% yearly interest rate is applied until the last year. The reimbursement period is set up with invested costs and its yearly interest so that toll period becomes 10 years longer than the period of reimbursement of invested costs. After all this causes a high economical burden on the passengers. The reimbursement plan for investment of the 2nd Urban Expressway, as the Table 4 indicates, is analysed in detail to find out the period for the reimbursement of total construction costs including its interests and that of total expenses without its interests.

Table 4. The redemption plan of the investment in The 2nd Urban Expressway

interest rate		10 %						
Class		1. dept at the beginn- ing of the year	2. interest	3. total dept (1+2)	4. toll	5. management cost	6. total income(4-5)	7. the rest dept (3-6)
Year	Gratis							
1993	0	162,000	12,150	174,150	6107	466	5,641	168,509
1997	4	172,920	17,292	190,212	18757	1,259	17,498	172,714
2002	9	154,030	15,403	169,433	22,688	1,459	21,229	148,205
2007	14	118,962	11,896	130,858	22,688	1,692	20,996	109,862
2012	19	63,982	6,398	70,380	22,688	1,961	20,727	49,654
2016	23	(2,132)	(213)	(2,346)	22,688	2,207	20,481	(22826)
Total			2,835					

note : private toll charge 600 won, van, cargo truck 800 won.

Hereabove, the total construction cost of the 2nd Urban Expressway, 451 billion won, is provided by the State government (Pusan Metropolitan) 298 billion won and the rest amount of the investment expenses (the amount outstanding) would be reimbursed by the toll period of 23 years. By the above table, 283.5 billion won can be assumed total interests of the investment expenses for 23 years. This amount of the interests equals to the half of the total construction costs for the 2nd Urban Expressway and is almost same as the total amount of Pusan Metropolitan's investment. That means the passengers of the roads pay the amount included the figures for the amount outstanding and the interest. However, as we regard only the figures for the amount outstanding excluding the interest will get paid back within only 6 years, as the above table shows. The private investment on the 2nd Urban Expressway makes the toll charge system unavoidable. The reimbursing process for the invested expenses takes 10 more years of delay regarding the interests. Futhermore it also gives users an economic burden by imposing a high toll fee for early reimbursement for the construction costs. Therefore, in case of the mutual participation of the government and private for investment of road facilities, the lowered portion of private investment and lowered interest can induce more traffic flows due to the less toll charge burden and result in less toll charging period required.

#### 4. THE ESTIMATION OF DIVERTED TRAFFIC VOLUME BASED ON THE CHANGES OF THE TOLL CHARGE

##### 4.1 Toll Charges and The Changes of Traffic Volume

Here I have analyzed the change of the traffic volume after and before the charging of the

## toll fee on the 1st and 2nd Urban Expressways of the City of Pusan.

### A. The 1st Urban Expressway

When the 1st Urban Expressway was built in 1980, it was free of charge for 7 months. During this period the traffic volume was 17,723 cars per day. But since it was charged in 1982, the traffic volume was reduced to 15,600 cars by 2,123 cars per day. This can be a reacting phenomena against the imposing toll fee. But as time passes by, the traffic volume increases day by day. As the Figure 1 shows, most of its users were privates in 1980 before the toll charge, and traffic volume of special truck was even lower. But in 1981 after toll charging, special truck's traffic volume was increasing. About two times more of special truck have used this road in 1981 compared to 1980. This can be regarded as the result of the recognition of the cargo truck drivers that using this road from the wharf could be more time saving than using any other streets to get on the Kyongbu Expressway. The traffic volume of buses were consistently increasing by the year of 1984, regardless the toll charging, but a little decreasing in 1985 and 1986. This can be analyzed that the above is resulted from the yearly decrease of the buses' traffic volume from 1982 to 1985. This is due to the movement of Express Bus terminal and East-West Regional bus terminal during the above period. Especially it has greatly affected the whole traffic volume in 1985. The increased traffic volume by up to Dec, 1992 can be explained by the unchanged toll fee and increased number of vehicles. here, the changing rate of the traffic volume during the free toll charge period in 1980 and toll charged period is about 88.02%. Therefore, diverted rate by the toll charge was about 11.97% which was -21.8% for private cars, -2.74% for buses, and -18.17% for trucks. It can be concluded that the diverted rate for private cars is the highest.

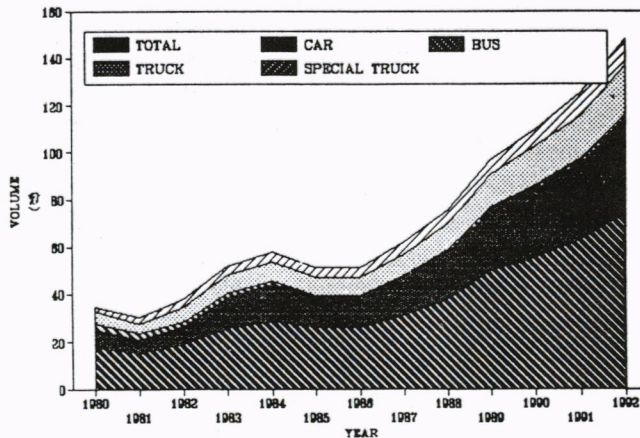


Figure 1. Traffic volume transition in The First Urban Expressway

### B. The 2nd Urban Expressway

The 2nd Urban Expressway has been built most recently and its construction costs is 3 times higher than that of the 1st Expressway, which might result in a big change of traffic volume. In terms of speed, the time period of 07:00 - 10:00 showed average speed at 43.54 Km/hr and 17:00 - 20:00 average speed at 44.80 Km/hr before the toll charging. However, After the toll charging, the time period of 07:00 - 10:00 showed average speed at 50.82 Km/hr and 17:00 - 20:00 average speed at 54.00 Km/hr. This can be interpreted that the toll charging reduces the traffic volume. The following table shows the change of traffic volume

surveyed.

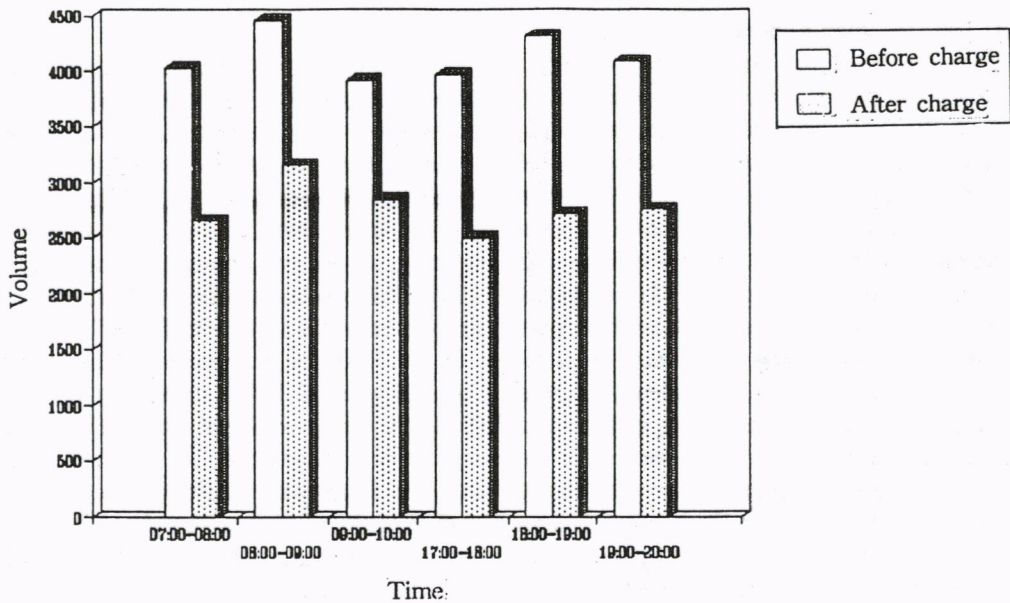


Figure 2. Traffic volume transition in the Second Urban Expressway

It is certain that the traffic volume has been changed by about 68% compared to the period before the tolling. In case of types of the vehicles, the volume of the passenger cars, taxicab, small sized trucks, big sized trucks and buses has been changed by about 69%, 60%, 73%, 65% and 26%. Here there wasn't much passing-by of the city buses, commute buses has more traffic volume during the peak time period before noon than after noon before tolling. After tolling, the before-noon-time zone and the after-noon-time zone show almost same traffic volume and the most-high-volumed time zone is from 7 P.M to 8 P.M. The small sized trucks do not really show the high response to the changes of the toll charge, which means their high concern to time-saving variable. Analyzing the traffic flows based on the direction before and after the toll charging can be divided into two directions, Munhyon-dong direction and Hakjang direction shown on the Table 5 as below.

Table 5. The transition of direction of the traffic volume due to the toll charge

A type of car	Fee	car		Taxi cab		Truck		Special Truck		Bus		Total	
		before charge	after charge	before charge	after charge	before charge	after charge	before charge	after charge	before charge	after charge	before charge	after charge
Hakjang → Munhyon-dong		8466	5722	1034	835	2353	1939	1182	836	46	53	17696	9377
			△2744		△199		△414		△346				△8319
Munhyon-dong → Hakjang		6787	4729	1227	561	2594	1476	805	485	283	31	11693	7282
			△2058		△666		△1118		▽320		△252		△4411

The traffic volume of Hakjang to Munhyon-dong is larger than that of Munhyon-dong to Hakjang, which is to show more traffic inflows to the downtown areas than that to any other areas. We can also see that the diverted rate (53%) to the direction to Munhyon-dong is much more sensitive to the tolling than that (62%) to the direction to Hakjang. This tells us the fact that people don't fall much inconvenient when getting into the city without being



tolled, however, they could be benefited from being tolled when getting towards the Hakjang direction.

The change of traffic volume in each entering ramps before and after tolling has been researched. The entering ramps for the 2nd Urban Expressway can be divided into Munhyon ramp, Jaeiljaedang ramp, Jinyang ramp, Bohun-Hospital ramp and Hakjang ramp shown as the Figure 4. The smallest-change for the traffic volume upon the toll-fee imposing is at Hakjang ramp point whose coefficient of utilization is 96.4%. This is to show that the vehicles getting into the Hakjang ramp to reach Munhyon-dong do not much care of the toll-fee imposing. The highest-changing of traffic volume upon toll-fee imposing is at Bohun-Hospital ramp showing coefficient of utilization, 25.1%. This is to show that there are a difficulty with waiting on the traffic light to get into the 2nd Urban Expressway and no efficiency to save the traveling time.

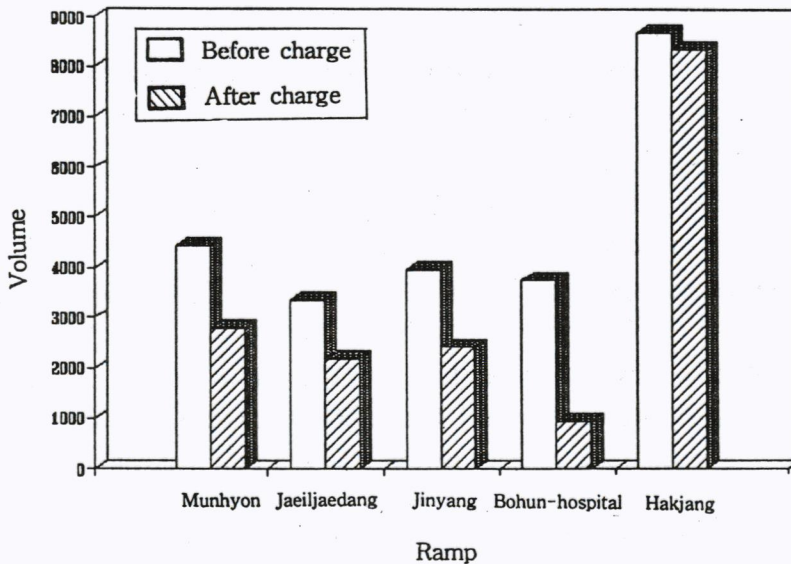


Figure 3. The change of traffic volume in each entering ramps

#### 4.2 Presumption Model of The Diverted Traffic Volume by The Toll Charge

Diverted traffic is the traffic that is diverted to the newly-constructed roads from the existing ones. When vehicles pass the several ordinary roads that are contrasted to toll roads, drivers can select a newly-constructed roads among several possible roads to reach his destination. Then This can be interpreted as "diverted traffic against the existing road".

And then, Even though the new road is tolled, there is a possibility of using the toll charged road, when users can take advantage of saved traveling time, pleasantness, and less congestion by using it.. This could be called as diverted traffic volume. Then the traffic volume on the toll tends to decrease temporarily. This changing traffic volume then is the diverted traffic volume upon the toll-fee imposing. As time passes without changing the level of toll charge, the increase of utilization for the toll depends on saved-traveling time rather than the steady toll fee.

The vehicles using toll roads for saving traveling time are subject to the degree to the toll - fee imposing. Therefore the indicators (index) of the diverted rate curve are traveling time and degree to toll charging. The reasons for this are following;

First, the factors such as pleasantness, congestion degree don't exist independently. They are relative to the traveling time. The less the traveling takes, the more pleasantness occurs. This means the high speed will bring the pleasantness by reducing the congestion degree.

Second, the payment of the toll fee is to be made to the road users considering costs for labors, safety, and management and maintain. Therefore, unnecessary traffic such as circulating traffic for parking spaces shall be removed from the toll road, which could lead to the achievement of less congestion.

On this study, the model of diverted rate curve with variables of traveling time and toll fee to estimate diverted traffic volume is formula (1) and (2).

$$P = \frac{1}{1 + \alpha x^\beta} \text{----- (1)}$$

P : Diverted rate for traffic volume on the toll imposed road

x : an independence variable

$$x = \frac{R}{T(G) - T(H)} \text{----- (2)}$$

T : Traveling time

G : Before toll charged    H : After toll charged    R : Toll charge

The comparative analysis between the 1st Urban Expressway and 2nd Urban Expressway must be reasonable to analyze this study. In case of the 1st Urban Expressway, it is possible to estimate an diverted traffic volume between 1980 and 1981, but not possible to estimate the traveling time after the tolling and traveling time before the tolling. So only the materials of the 2nd Urban Expressway are analyzed and To analyze these the additional materials from the traffic count are used. And the average traveling time of G is about 11 minutes and that of H for about 9 minutes. To estimate parameters of the formula of each models upon an illustration variable of P is following.

$$P = \frac{1}{1 + 0.09975x^{0.97283}} \text{----- (3)}$$

( F = 6.89,    Signif. of F = 0.97283 )

R<sup>2</sup> explaining of the above diverted-rate model has high illustration of 63%. And F showing the significance level of the model comes up with significance level 0.05.

### 4.3 Estimating Diverted Traffic Volume

The diverted rate of traffic volume calculated by the above diverted rate formula (3) is

used to estimate the limitation of the toll charge upon the change of the toll fee. The result is shown on the Figure 4 below.

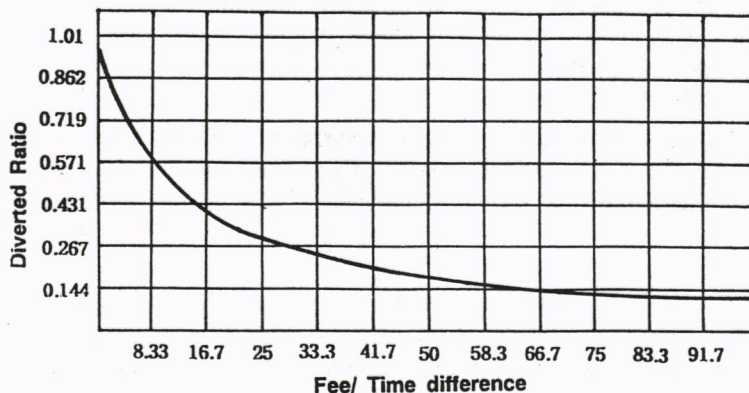


Figure 4. The diverted rate graph the toll road

As it is shown on the Figure 5 above, the more toll fee increases the more the diverted rate persistently decreases. However when it reaches to the certain point, the decrease of the diverted rate gets a slowdown. The limitation of toll fee on toll road can rely upon the traffic stream on each service level of express highway. If the time saving factor upon the payment of the toll fee is achieved, the users use toll roads even though there is an increase of toll fee. Therefore the limitation of toll fee depends on the level of service. Here we regard the point D, E on the service level of express highway as the limitation of the toll fee. The level of service of express highway can be judged by V/C ratio which is Peak-hour Traffic volume (PCU/Hr) over traffic volume(PCU/Hr). When L.O.S reached "D", the V/C ratio is above 0.81 and when reaches "E" the V/C ratio is above 0.91. And the present traffic volume on the express highway is 4,400 cars(PCU/Hr) and peak-hour traffic volume shows 3,778 cars(PCU/Hr). So now the diverted rate, 68% on the toll fee, 600 won, results in the V/C ratio 0.68.

At the above state, assuming the L.O.S "D" on the Expressway the limitation of toll fee, when V/C ratio is 0.81 that is highered by 100-won from the moment level at 3,558 cars(PCU/Hour) of Peak-hour traffic volume.

Assuming the L.O.S "E" of Expressway the limitation of toll fee, when V/C ration is 0.81 that is lowered by 500-won from the moment level at 3,998 car(PCU/Hr) of Peak-hour Traffic volume

## 5. CONCLUSION

This study's purpose is to systemize an exchange rate formula for Pusan's toll roads. By using the exchange rate formula of "AASHO", we can estimate diverted traffic volumes when fees are manipulated.

The result induced from this study is follow:

1) The reimbursement periods for toll roads in Japan are set up for 30 years, in contrast, Pusan's are set up for about 19 to 23 years. Pusan's intentions is to get an early

reimbursement for investment of the toll roads with the high toll fees in short time periods. And a 10%~12% yearly interest rate is applied throughout the reimbursement periods, which results in the increase of the users' financial burden; The reimbursement periods are set equally with the principal sum of the invested cost, and the yearly interest. By doing this the toll fee period imposed have become about 10 years longer than the reimbursement periods for the only principal sum.

Therefor, when private companies and city governments take part in the investment of the road facilities together, the investment rate by private companies or the yearly interest rate on the privately-invested capital should be minimized. This induces more users for the toll road.

2) The diverted rate by imposing toll charges, in case of the 1st Urban Expressway, is generally 88.2%. This is in 1981 (post-toll charging period) over 1980 (pre-toll charging period). In types of vehicles, private cars show a 78.7% of diverted rate, buses 97.3%, general-goods-delivery vehicles 81.8%, and special-goods-delivery vehicles 151.5%. However at this point where no change of toll fee is imposed, the traffic volume seems getting increased. The 68% of diverted rate of traffic volume upon the before (in 1993) and after (in 1994) toll charging periods on the 2nd Urban Expressway explains the high influence of the toll charging to the vehicles in the city. The diverted rate formula shows a 63% of relatively high determiner variable, and, The significance Level by F-value indicated to significant within 0.05.

The limiting point of toll fee level is set to when the traffic volume using toll roads upon the change of toll fee reaches the level of service "D" and "E". When regarding level of service "D" as a limiting point, 700 won for the toll charge showing a 64% of diverted rate in analyzed as a proper level of toll-fee imposition. And when regarding level of service "E" as a limiting point, 500won-line showing a 72% of diverted rate is analyzed as a proper level. In case of the 2nd Urban Expressway, the diverted traffic volume is surveyed and analyzed, on this study, in partially opened state so that the survey and study on diverted traffic volume should be done continuously after the fully opened state.

In this study, the comprehensive analysis on free of charge to more than 3 passengers' riding cars recently carried by TDM should be implemented to establish diverted rate model, which is regarded as the future assignment.

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