

**Real-time Cycle-based Delay Predictive Modeling
on the Signalized Intersections in Pusan Area**

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沈 亮 珠

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Abstract

Today the arterials play a key role in urban transportation. However, they experience a severe congestion with the mixed traffic on the signalized intersections regardless of the peak periods. Thus, the purpose of this study is to identify the real-time cycle-based traffic characteristics, construct the delay predictive models (DPM) depending on the time-periods and finally determine the ranking of the factors affecting the delay on the signalized intersections in urban area.

From the analyses of the real-time traffic characteristics, the construction and verification of delay models, and the determination of the ranking in the factors on the delay models, the following results were obtained :

) Traffic flow did not show a distinct difference depending on the time periods. Rather, more traffic flows were concentrated on the signalized intersections in the non-peak periods when compared with the on-peak periods.

) The volume-to-capacity (v/c) ratio was proved to be a key variable in delay model construction on the signalized intersection. Also, the variables used in the model construction showed the appropriateness in the travel characteristics on the signalized intersections.

) Most of the delay models were shown to have a higher explanatory power for the delay predictive model construction and verification with the high R^2 values.

) The left-turn link showed a key factor affecting delay on the 3-leg signalized intersections, but the thru link showed a key factor affecting delay on the 4-leg intersections. Also, the passenger car showed a key factor affecting delay on the 3-leg or 4-leg signalized intersections.

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NOMENCLATURE

s	saturation flow rate in vphg
s_0	ideal saturation flow rate per lane in pcphgpl
V_{15}	traffic volume during peak 15 minutes in veh/15min
V	traffic volume during peak 1 hour in veh/hr
c	capacity of lane group in pcph
c_0	ideal capacity per lane in pcphgpl
W	lane width in m
D	uniform delay in veh-hr/hr
m_t	queue length in vehicles during step t
N	number of steps in the cycle
D_{ro}	random-plus-oversaturation delay in veh-hr/hr
X	degree of saturation, defined as v/c
T	period length, normally 60 minutes for unsaturated conditions
v	volume on the link
m	function of arrival type

D	average stopped delay per vehicle in sec/veh
X_P	v/c ratio of passenger car
X_V	v/c ratio of van
X_B	v/c ratio of bus
X_T	v/c ratio of truck
U	g/C ratio
g	green time in sec
C	cycle length in sec

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가

TRANSYT - 7F

1.3

1998 ¹⁾(highway capacity manual, HCM)

(average control delay)

(uniform control delay)

(incremental delay)

(residual demand delay) 가

, HCM

(progression factor, PF)

1985 HCM

²⁾(Korea

highway capacity manual, KHCM)

TRAF-NETSIM

(s_0) (s)
 v/c offset
 , US HCM
 Karl Westby Nancy Nihan³⁾
 24 ,
 37
 가
 .
 Panos D. Prevedouros Cathy A. Koga⁴⁾ Chicago Honolulu
 1985 HCM 1994 ,) 1985 HCM
 1994 (level of service, LOS) 가
 ,) (ideal saturation flow, s_0)
 $s_0 = 1,900$ pcphgpl 가
 ,) (actuated signal operations)
 가
 Rahmi Akcelik⁵⁾ 1985 HCM
 Australian Canadian
 HCM
 ,
 .
⁶⁾ ()
 HCM 7가 4가
 HCM, KHCM NCHRP(national cooperative

highway research program 399)

,

.

7)

(steady-state) 가

, (stationary) 가

(time-dependent)

, , offset ,

.

8)

US HCM, TRANSYT - 7F

가

,

가

(phase)

가

,

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1.4

3 3 , A (), B (), C
 () 3 4 , D (), E ()
), F () 2000 3 2000 6 4

2

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, , ,
(07:00 09:00),

(10:00 12:00), (14:00 16:00), (18:00
20:00) 4가 .

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TRANSYT-7F Version 8.2

가 ,

MS

Office 97 SAS Version 6.12

SPSS Window Version 7.5

가 .

2.

09:00), (10:00 12:00, 14:00 16:00), (18:00 20:00) (07:00
3 4
. 3 4

Fig. 2.1, Fig. 2.2

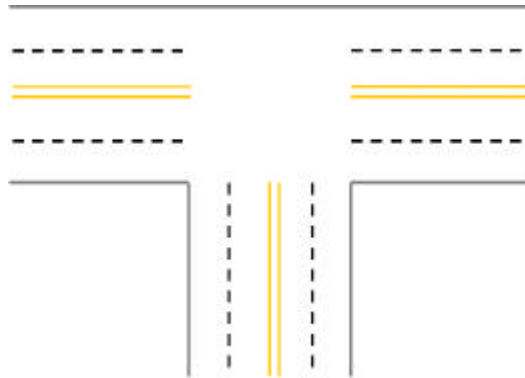


Fig. 2.1 3-leg intersection

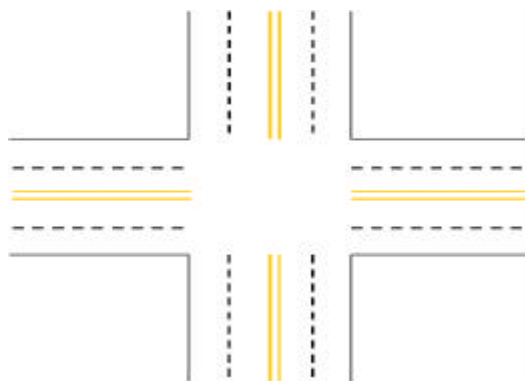


Fig. 2.2 4-leg intersection

2.1

4 (24 Hours),
 (AM peak; 07:00 09:00), (Non peak; 10:00 12:00, 14:00 16:00),
 (PM peak; 18:00 20:00) .
 (passenger car equivalent, PCE)
 PCU/hr, passenger car unit .
 passenger car, van, bus, truck 4가 Table 2.1
 . van 1.0 ton , truck

Table 2.1 Passenger car unit for heavy vehicles(unit, pcu)

vehicle type	passenger car	van	bus	truck
pcu	1	1.2	2.0	2.5

3 B
 . 17.7%, 4 D .
 17.4% ,
 , D F
 , 가

가

A , A 가

가 가 . (

Table 2.2, Fig. 2.3, Fig. 2.4)

(peak

hour factor, PHF)가 , 1

15 15

(2.1) .

$$PHF = \frac{V}{4 \times V_{15}} \quad (2.1)$$

,

PHF ;

V_{15} ; 15 (veh/ 15min)

V ; 1 (veh/hour)

0.95

. (Table 2.2)

, PHF

가

Table 2.2 Traffic characteristic shifts depending on the periods

3-leg intersection												
intersection	A				B				C			
period	24 Hours	AM peak	Non peak	PM peak	24 Hours	AM peak	Non peak	PM peak	24 Hours	AM peak	Non peak	PM peak
volume (pcph)	7,933	7,461	8,150	7,969	4,761	5,029	4,473	5,069	5,216	5,381	5,078	5,325
PHF	0.96	0.94	0.97	0.97	0.94	0.90	0.96	0.95	0.96	0.94	0.97	0.94
4-leg intersection												
intersection	D				E				F			
period	24 Hours	AM peak	Non peak	PM peak	24 Hours	AM peak	Non peak	PM peak	24 Hours	AM peak	Non peak	PM peak
volume (pcph)	9,586	10,073	9,164	9,945	4,192	4,089	4,194	4,291	9,041	9,486	8,959	8,759
PHF	0.95	0.91	0.97	0.95	0.95	0.93	0.96	0.95	0.95	0.91	0.98	0.94

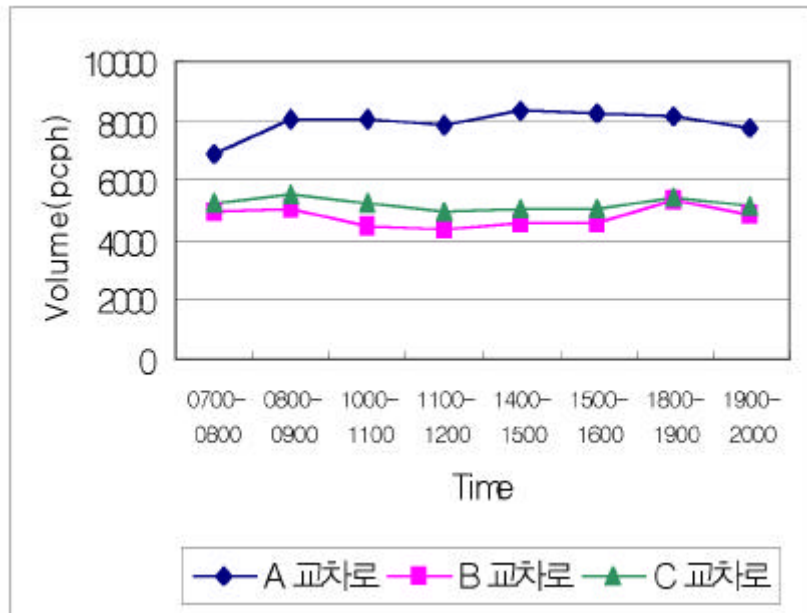


Fig. 2.3 Volume distribution on 3-leg intersection

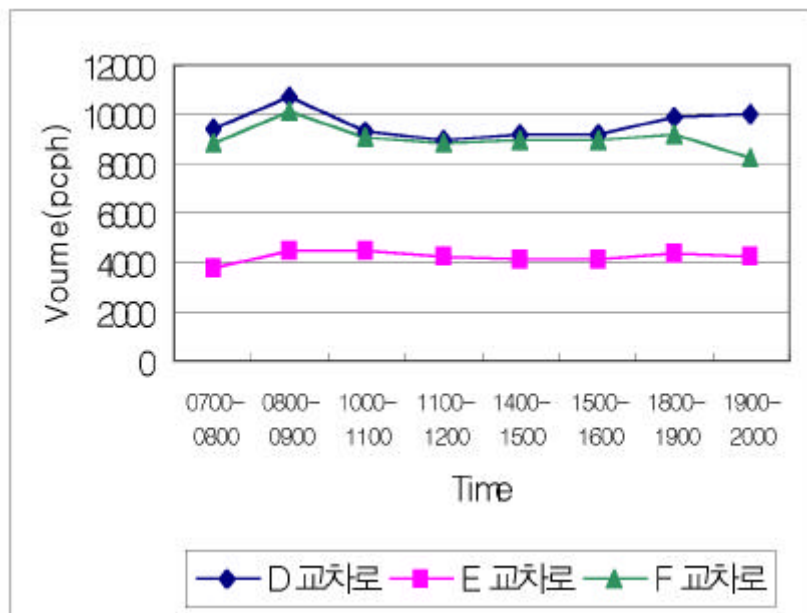


Fig. 2.4 Volume distribution on 4-leg intersection

2.2

(c)

(HCM)

(2.2)

$$c = c_0 \times \left\{ 1 + \left(W - \frac{3.6}{9} \right) \right\} \quad (2.2)$$

,

c ; (pcph)

c_0 ; (pcphgpl)

W ; (m)

(c_0) HCM 3.6m (travel

capacity) 1,900pcphgpl

2,250pcphgpl, .

2,100pcphgpl,

2,000pcphgpl

2.7m 4.4m , KHCM

3.0m .

2 6 , A

가

가

2.3

3 3
 , 130 180 , (effective green
 time ratio, g/C) 0.15 0.76 4 E
 4 , D F 5 , 150
 160 , 0.06 0.47
 130 180
 가 가 , 가 가

spillback ()

, A E

180 , C , 160 , 가
 , D F
 spillback
 . (Table 2.3) ,
 가 .

Table 2.3 Signal characteristic shifts on the intersections(unit, sec.)

	3-leg intersection			4-leg intersection		
intersection	A	B	C	D	E	F
phase No.	3	3	3	5	4	5
cycle(sec)	150	130	180, 160	150	150	160

2.4

TRANSYT - 7F
 (version 8.2)
 (2.3) .

$$D = D_u + D_{ro} \quad (2.3)$$

D ; (sec)
 D_u ; (sec)
 D_{ro} ; (sec)

(uniform delay, D_u)

$$D_u = \frac{\sum_t^N m_t}{N} \quad (2.4)$$

D_u ; (veh-hr/hr)
 m_t ; step t
 N ; step

(D_{ro})

$$D_{ro} = 900TX^2 \left\{ (X - 1) + \sqrt{(X - 1)^2 + \frac{mX}{cT}} \right\} \frac{v}{3600} \quad (2.5)$$

D_{ro} ; (veh-hr/hr)
 X ;
 c ; (vph)
 v ; (vph)

T ; (period length, 60)
 m ;

ratio) 가 v/c (volume to capacity
. 3 , 4
, v/c 가 1.0
,
가
가
. (Fig. 2.5 Fig. 2.10)

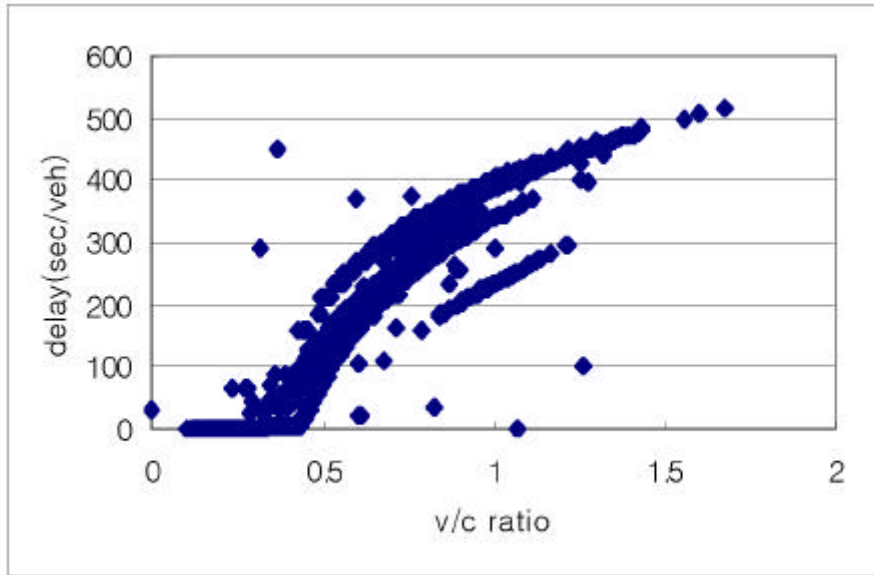


Fig. 2.5 Relationship between v/c ratio and delay on A intersection

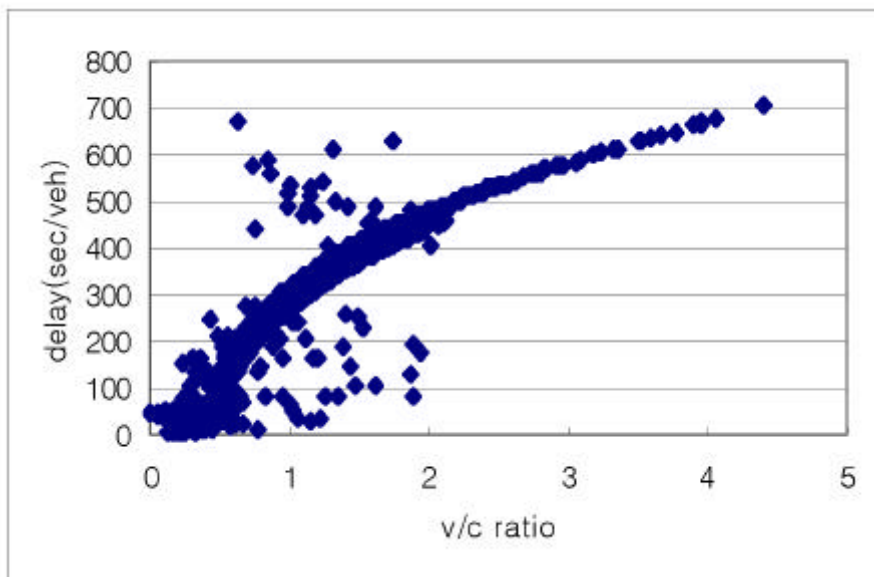


Fig. 2.6 Relationship between v/c ratio and delay on B intersection

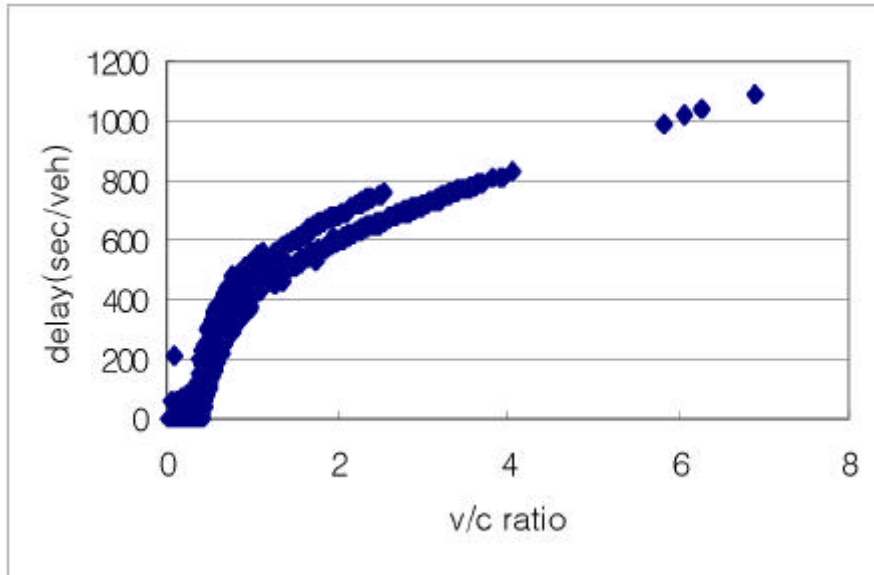


Fig. 2.7 Relationship between v/c ratio and delay on C intersection

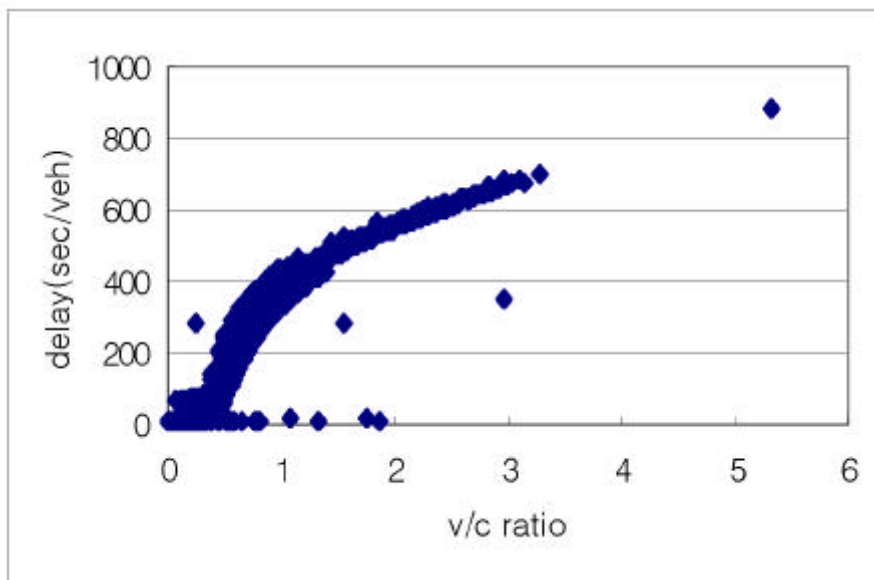


Fig. 2.8 Relationship between v/c ratio and delay on D intersection

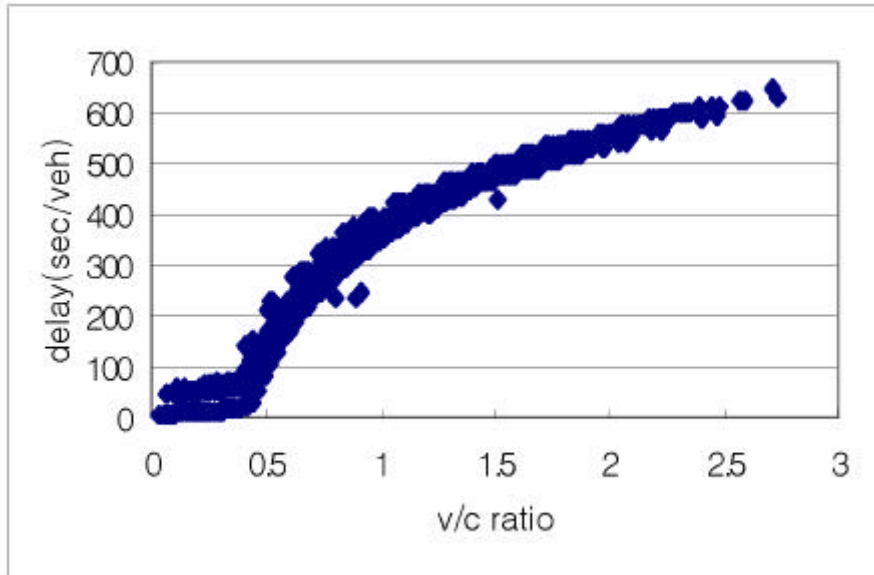


Fig. 2.9 Relationship between v/c ratio and delay on E intersection

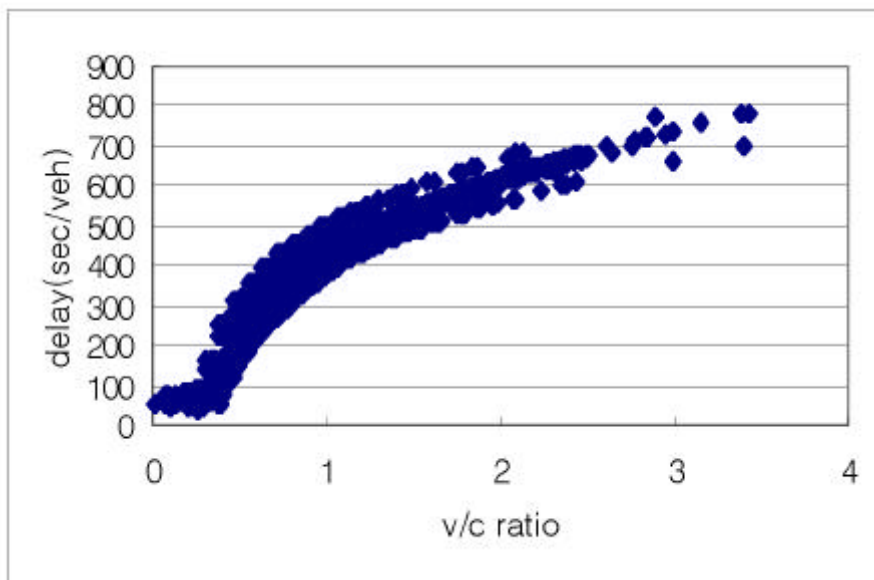


Fig. 2.10 Relationship between v/c ratio and delay on F intersection

3.

TRANSYT - 7F(ver. 8.2)

(g/C ratio)
model, DPM)

3 , 4

, v/c
(delay predictive

3.1

3.1.1

(multiple regression)

(multiple regression)

가

v/c

3 , 4

v/c

4가

v/c

D : (sec/veh)
 X_P : v/c
 X_V : v/c
 X_B : v/c
 X_T : v/c
 U : (g/C)

3.1.2

regression model) , (multiple
 가
 R^2
 (multicollinearity)
 1)(stepwise regression method)
 , Klein

3.1.3

(measure)) R^2 가;)
 (+,-)가 , 가
 가 가;) ()가 가; 3가
 .
 1) 가 , 가

3.2

3.2.1 3

	v/c (X_P)	(D)
Paris-Winsten	2 (YW)	가 ,
		0.000
		(R^2)
	0.865	0.917, 0.941,
	0.944	
	Durbin-Waston	2 가
		가 .
가 가 '+		v/c 가 가
'-'		(U)가 가 가
		가 .

(Table 3.1)

Table 3.1 Delay predictive models(DPM) constructed on 3-leg intersection

period	Model					
24 Hours	$D = 48.338068 + 380.160087X_P - 69.111545X_P^2 + 234.787608X_V + 263.986414X_B + 215.028537X_T - 121.783795U$					
	R^2	0.917	$Prob > F$	0.000	DW	2.1703
AM peak	$D = 41.965521 + 390.284123X_P - 74.236169X_P^2 + 266.359593X_V + 258.559007X_B + 154.748964X_T - 100.145828U$					
	R^2	0.865	$Prob > F$	0.000	DW	1.9760
PM peak	$D = 23.507788 + 391.399317X_P - 64.760870X_P^2 + 209.902632X_V + 247.447134X_B + 217.589078X_T - 88.094311U$					
	R^2	0.941	$Prob > F$	0.000	DW	2.1885
Non peak	$D = 22.395533 + 484.092737X_P - 141.531850X_P^2 + 223.486074X_V + 283.244726X_B + 211.657737X_T - 121.160408U$					
	R^2	0.944	$Prob > F$	0.000	DW	1.9957

3.2.2 4

$v/c (X_P)$ (D)
2 가 ,
 Paris-Winsten 2 (YW)
 , 0.000
 (R²)
 0.964, 0.960, 0.969,
 0.959 0.95
 , Durbin-Waston
 2 가 가
 v/c 가 가

가 가 ‘+’ , (U)가 가 가
 ‘-’
 가

(Table 3.2)

Table 3.2 Delay predictive models(DPM) constructed on 4-leg intersection

period	Model					
24 Hours	$D = 40.707743 + 508.510889X_P - 144.216888X_P^2 + 287.365850X_V$ $+ 269.748899X_B + 287.853087X_T - 174.293289U$					
	R^2	0.964	$Prob > F$	0.000	DW	2.1307
AM peak	$D = 66.224408 + 399.753301X_P - 69.365089X_P^2 + 260.801890X_V$ $+ 282.453009X_B + 234.907076X_T - 154.230330U$					
	R^2	0.960	$Prob > F$	0.000	DW	2.0413
PM peak	$D = 59.141548 + 492.534983X_P - 131.417862X_P^2 + 252.719172X_V$ $+ 262.954192X_B + 261.118340X_T - 211.804396U$					
	R^2	0.969	$Prob > F$	0.000	DW	2.0792
Non peak	$D = 52.658490 + 526.582799X_P - 172.111403X_P^2 + 289.044925X_V$ $+ 273.367937X_B + 283.074572X_T - 212.758395U$					
	R^2	0.959	$Prob > F$	0.000	DW	2.0325

3.3

(correlation analysis)

가 3

0.90 , 4 0.95
 . (Table 3.2, Fig. 3.1, Fig. 3.2)

Table 3.3 Correlation coefficients of tests depending on the periods

	3-leg intersection				4-leg intersection			
	24 Hours	AM peak	PM peak	Non peak	24 Hours	AM peak	PM peak	Non peak
<i>R</i>	0.924	0.901	0.936	0.947	0.955	0.960	0.966	0.960

) *R* = Correlation coefficient

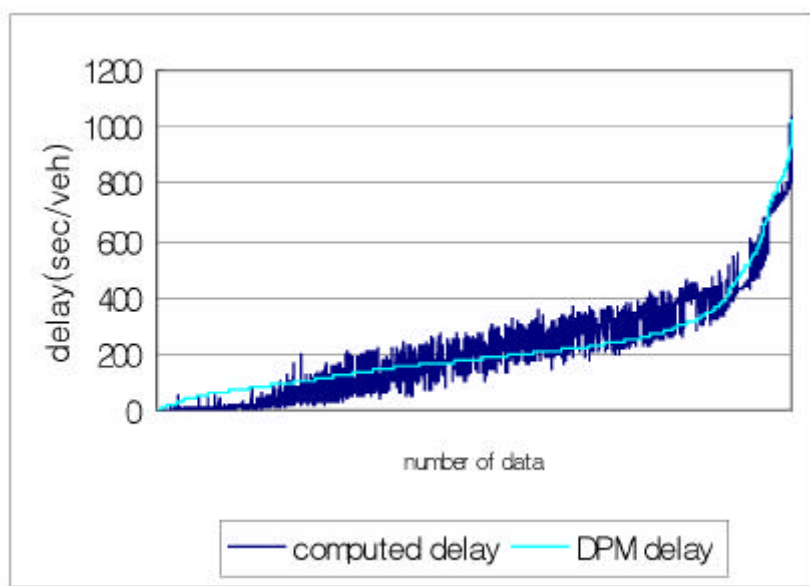


Fig. 3.1 Comparison of computed and predicted delay on 3-leg intersection

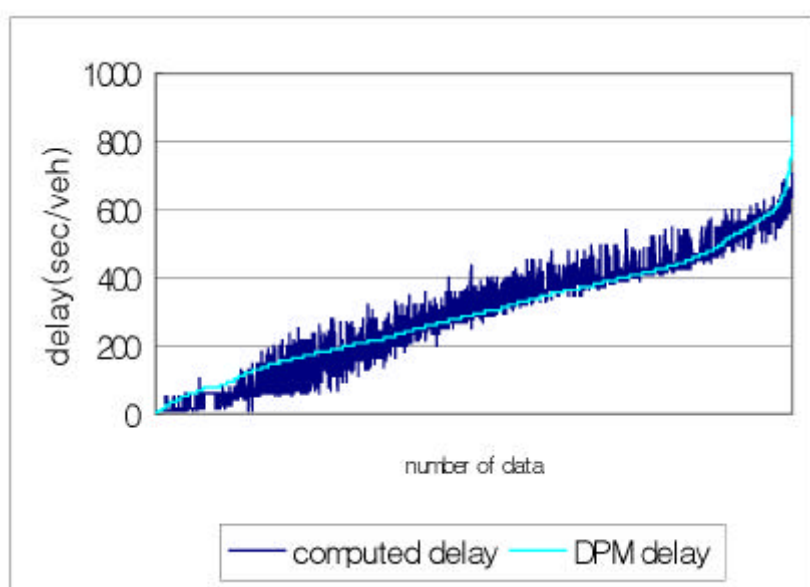


Fig. 3.2 Comparison of computed and predicted delay on 4-leg intersection

3.4

(factor analysis)

, 가

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3, 4

,

, , v/c

3 가

가

,

, . 4

3 , 4

가 , 3, 4 v/c 가

v/c

가

가

. (Table 3.4, Table 3.5)

Table 3.4 Delay factor matrix on 3-leg intersection

	Passenger car	Van	Bus	Truck
Left turn				
Thru				
Right turn				

) 24 Hours

	Passenger car	Van	Bus	Truck
Left turn				
Thru				
Right turn				

) AM peak

	Passenger car	Van	Bus	Truck
Left turn				
Thru				
Right turn				

) PM peak

	Passenger car	Van	Bus	Truck
Left turn				
Thru				
Right turn				

) Non peak

Table 3.5 Delay factor matrix on 4-leg intersection

	Passenger car	Van	Bus	Truck
Left turn				
Thru				
Right turn				

) 24 Hours

	Passenger car	Van	Bus	Truck
Left turn				
Thru				
Right turn				

) AM peak

	Passenger car	Van	Bus	Truck
Left turn				
Thru				
Right turn				

) PM peak

	Passenger car	Van	Bus	Truck
Left turn				
Thru				
Right turn				

) Non peak

4.

HCM, KHCM,

TRANSYT - 7F

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가 130 180

가 가

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spillback D F ,

가

) 1.0 v/c 가

) 3 , 4 0.000 (R²) 가 , 3 가 0.90 , 4 0.95 , 3 4 3 가 4

) , 4 가 가 , 3 , 4 v/c가 가 3 , 4

4 , 3 ,
4 3
. , 3
v/c
가
.
,
offset
가
,
)
3 , 4
가
)
가
.

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