CHAPTER 4 COMPUTATIONAL EXPREIMENTS AT AN ISOLATED INTERSECTION

To investigate the effectiveness and robustness of the proposed GFLC and AGFLC models, this chapter firstly conducts the TPS with GFLC and AGFLC at an isolated intersection. Section 4.1 and 4.2 describe the results of an exemplified example and a field case, respectively.

4.1 Exemplified Example

4.1.1 Data and Parameters

(1) Traffic data

To investigate the effectiveness of the proposed GFLC and AGFLC models, an exemplified example is first conducted at an intersection with configuration shown in Figure 4-1. Assume that the intersection has two lanes in each approach with saturation flow 1800 pcu/hr/lane. Ten-hour five-minute flow rates in TPS control directions and non-TPS directions, as illustrated in Figure 4-2, are randomly generated at the range of 0.4~0.6 and 0.2~0.3 degree of saturation, respectively. Buses are assumed to be arriving in *Poission* distribution with $\lambda = 0.17$ veh/sec. The average loading factors for a private car and bus are assumed to be 2 and 40 persons, respectively.

The cycle length and green time of pre-timed signal are determined by Webster's minimum delay model as 156 and 100 seconds. The other parameters are set as G_{max}=130 seconds, G_{min}=20 seconds, AR=3 seconds, H=13 seconds, and L=10 seconds. For the simplicity of the simulations, the H and L are assumed the same to each actuated bus without the consideration of different traffic situations encountered by the buses.

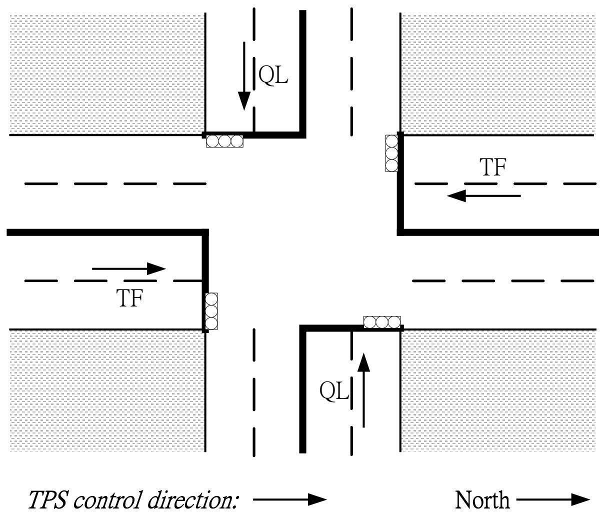


Figure 4-1 Configuration of the exemplified example at an isolated intersection.

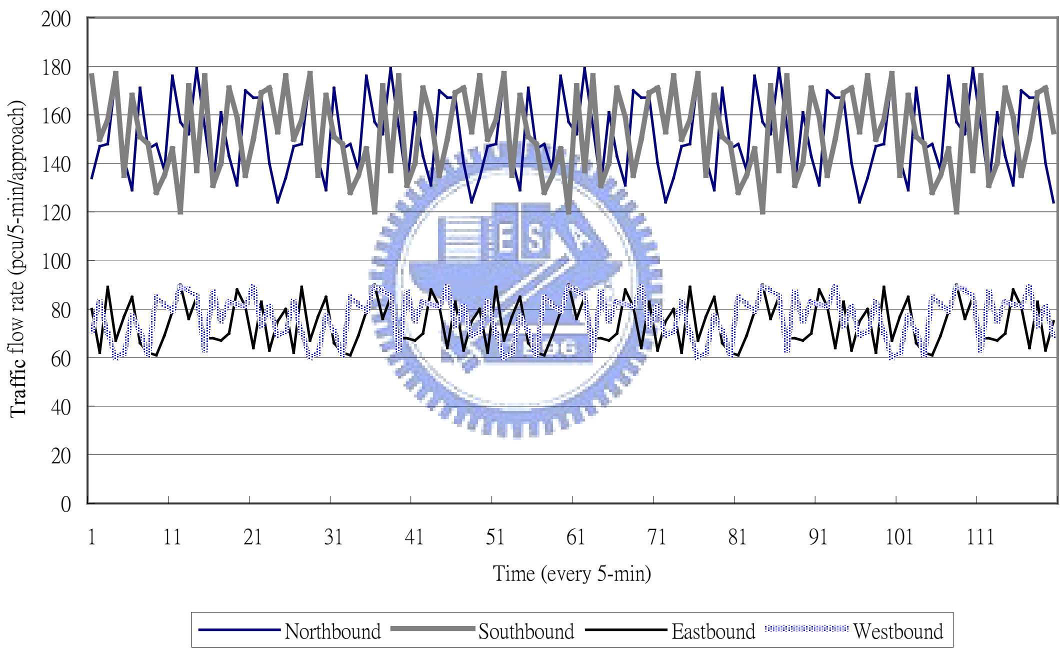


Figure 4-2 Assumed traffic flows at an isolated intersection.

(2) Parameters Settings

To choose appropriate parameters of GA and ACO algorithms, the learning results with various settings of parameters are investigated. The results suggest that the parameters of GA algorithms for selecting fuzzy rules and tuning membership functions are set as follows: population size=100, crossover rate=0.9, mutation rate=0.1, a=0.35, h=0.5, δ=80%, ε=0.001, N_t=0.5, and the center of gravity method is employed for defuzzification.

Moreover, test results of various parameter settings also suggest that the parameters of ACO algorithms for selecting fuzzy rules are set as follows: α=2, β=5, ξ=0.1, ρ=0.1 and q_0=0.3. The number of ants (*K*) is 25 (equal to the number of antecedents) and the maximal iteration (t_{max}) is 100.

To minimize the total person delay of the intersection, it is reasonable to regard that *TF* has a positive proportion to *NE* and *QL* has a negative proportion to *NE*. Therefore, referred to the MacVicar-Whelan rule base (Macvicar-Whelan, 1976), the predetermined rule table for computing the heuristic information, represented by reasonability index, can be defined as Table 4.1. Besides, the heuristic information on the arcs connecting exclusion set with all antecedents (θ_{i6}) is assumed to be 0.5.

Table 4.1 Predetermined rule table for heuristic information

y (NE)		*x_1(TF)*				
		NL	*NS*	*ZE*	*PS*	*PL*
x_2(QL)	*NL*	*ZE*	*PS*	*PL*	*PL*	*PL*
	NS	*NS*	*ZE*	*PS*	*PS*	*PL*
	ZE	*NL*	*ZS*	*ZE*	*PS*	*PL*
	PS	*NL*	*ZS*	*NS*	*ZE*	*PS*
	PL	*NL*	*ZL*	*NL*	*NS*	*ZE*

Note: *NL*: negative large, *NS*: negative small, *ZE*: zero, *PS*: positive small, *PL*: positive large.

(3) Fitness value

The performance of signal control at intersections are frequently measured in terms of total number of stopped vehicles, proportion of stopped vehicles, average vehicle delays and total vehicle delays, etc. This study aims to minimize the total person delay (*TPD*) to manifest the implementation of TPS. Thus, the objective function (*E*) is:

$$E = TPD \tag{4.1}$$

and the fitness value of GA can be defined as:

$$f = \frac{1}{E} = \frac{1}{TPD} \tag{4.2}$$

Furthermore, the initial pheromone of ACO is set as the objective function simulated by the predetermined rule table with equally distributed membership functions. It can be described as:

$$\tau^0 = \frac{1}{E_p} \qquad (4.3)$$

where E_P represents the value of the *TPD* simulated by a predetermined rule table with equally distributed membership functions.

Previous studies usually employ traffic simulation software to evaluate the performance of signal control models; however, it would be too time-consuming for the evolution of genetic generations. This study employs an analytical approach with fluid approximation to estimate vehicle delays for each cycle under different TPS strategies. The estimation is depicted in Figure 4-3. Bus delays are evaluated one-by-one depending on whether they are stopped at the intersection or not. Then person delays can be acquired by multiplying the loading factors.

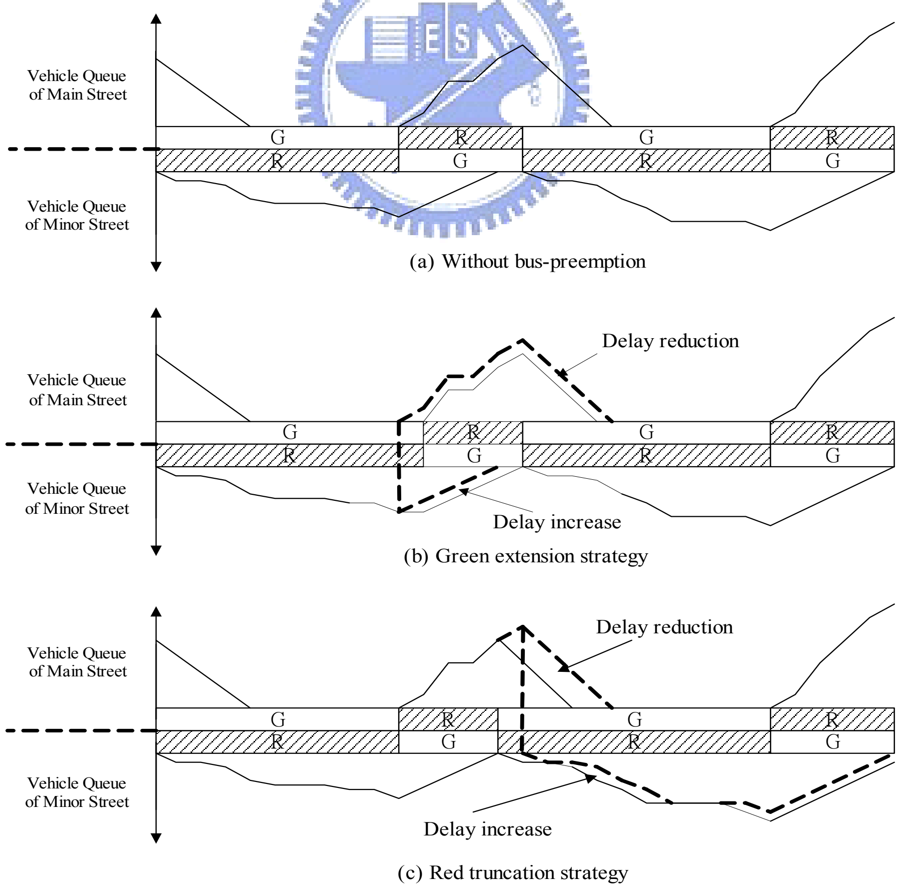
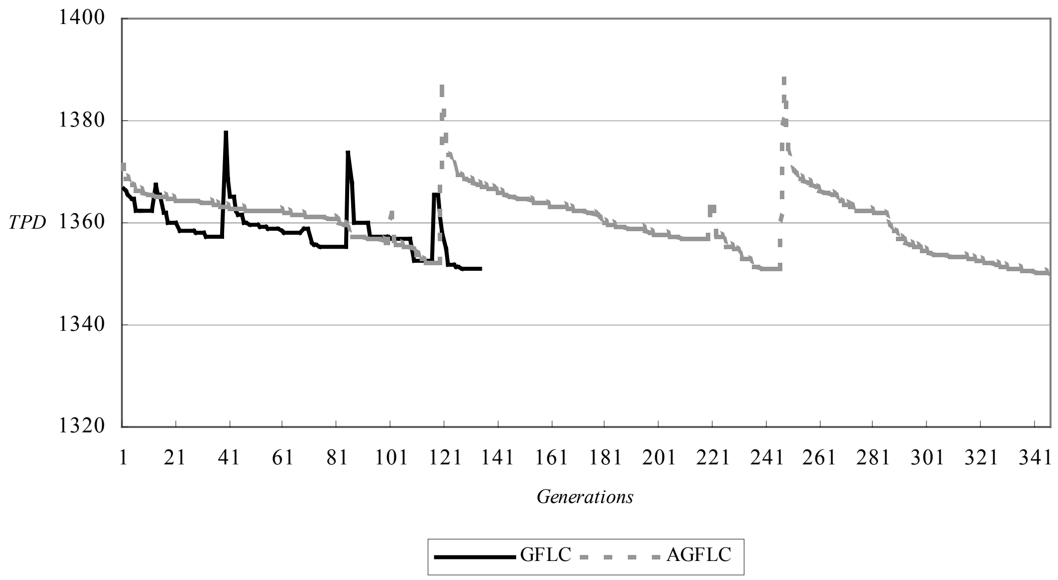


Figure 4-3 Estimation of vehicle delays at an isolated intersection.

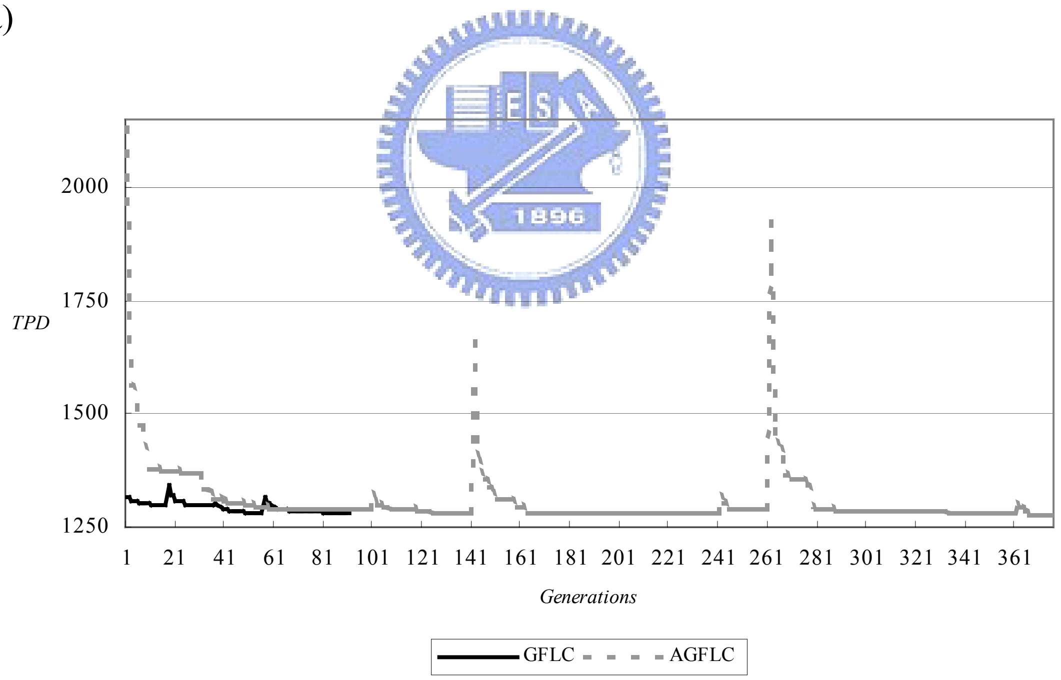
4.1.2 Learning Results

Figure 4-4 depicts the evolving processes of applying the GFLC and AGFLC models to green extension and red truncation TPS strategies. In green extension, both the GFLC and AGFLC converge after 3 iterative evolutions. The GFLC has 134 generations progressed where the value of *TPD* decreases from 1366.6 to 1350.8 person-hours. The AGFLC has a total of 346 ant iterations and genetic generations. The value of *TPD* decreases from 1371.2 to 1350.0 person-hours. While in red truncation, the GFLC converges after two iterative evolutions with 91 generations progressed where the value of *TPD* decreases from 1317.7 to 1278.7 person-hours. The AGFLC converges after 3 iterative evolutions with a total of 376 ant iterations and genetic generations where the value of *TPD* decreases from 2131.1 to 1276.0 person-hours. Both the processes in green extension and red truncation indicate that although the AGFLC can achieve the lower *TPD*, it is less efficient than the GFLC. Besides, the evolving processes also indicate that the converging variation of *TPD* in the learning processes is larger in the red truncation than in the green extension strategy.

The selected fuzzy rules and tuned membership functions for the GFLC and AGFLC are presented in Figures 4-5, 4-6 and 4-7. When implementing green extension strategy, as shown in Figure 4-5 (a1) and (a2), a total of 22 fuzzy rules are selected by the GFLC and 24 fuzzy rules by the AGFLC. While implementing red truncation strategy, as shown in Figure 4-5 (b1) and (b2), a total of 22 fuzzy rules are selected by the GFLC and 17 fuzzy rules by the AGFLC. However, because there are still too many rules in the rule base, the explanation of the reasonability of the rule selection result is not easy. As to the tuned membership functions shown in Figures 4-6 and 4-7, the shapes of membership functions learned from GFLC and AGFLC are not exactly the same.



(a)



(b)

Figure 4-4 Evolving process of GFLC and AGFLC of the exemplified example at an isolated intersection: (a) green extension strategy, (b) red truncation strategy.

y (NE)		*x_1(TF)*				
		NL	*NS*	*ZE*	*PS*	*PL*
x_2(QL)	*NL*	*NL*	*PL*	*ZE*	*PS*	*PS*
	NS	*PS*	*PL*	*NL*		*PL*
	ZE	*PL*	*ZE*	*PL*	*ZE*	*NS*
	PS	*NL*	*NL*	*PS*	*ZE*	
	PL	*PL*		*ZE*	*NS*	*PS*

(a1)

y (NE)		*x_1(TF)*				
		NL	*NS*	*ZE*	*PS*	*PL*
x_2(QL)	*NL*	*ZE*	*PS*	*PL*	*PS*	*PL*
	NS	*PL*	*PL*	*PS*	*PS*	*ZE*
	ZE		*PS*	*PS*	*PS*	*PS*
	PS	*NS*	*ZE*	*NL*	*NS*	*ZE*
	PL	*NL*	*NL*	*ZE*	*NS*	*NS*

(a2)

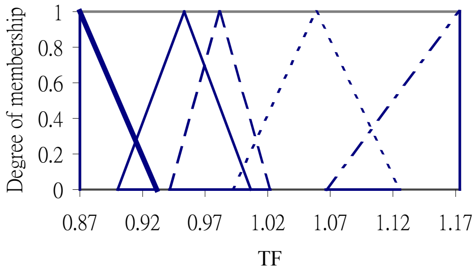
y (NE)		*x_1(TF)*				
		NL	*NS*	*ZE*	*PS*	*PL*
x_2(QL)	*NL*	*NL*	*NS*		*NS*	*ZE*
	NS	*PS*			*NL*	*NL*
	ZE	*NL*	*PS*	*PL*	*PL*	*PS*
	PS	*PL*	*NL*	*ZE*	*NS*	*NS*
	PL	*PS*	*NL*	*NL*	*ZE*	*ZE*

(b1)

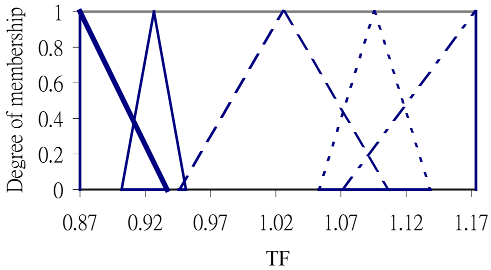
y (NE)		*x_1(TF)*				
		NL	*NS*	*ZE*	*PS*	*PL*
x_2(QL)	*NL*	*NS*	*NL*		*NS*	
	NS	*ZE*	*PS*	*ZE*		
	ZE	*PS*		*ZE*	*PS*	
	PS	*PS*	*PS*	*NL*	*PS*	*PS*
	PL	*ZE*			*ZE*	*ZE*

(b2)

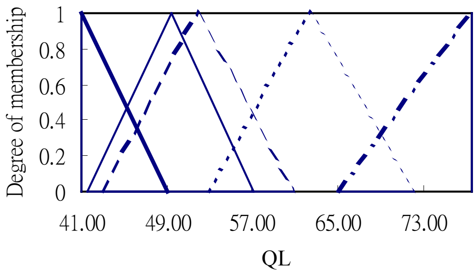
Figure 4-5 Selected fuzzy rules of the exemplified example at an isolated intersection: (a1) green extension with GFLC, (a2) green extension with AGFLC, (b1) red truncation with GFLC, (b2) red truncation with AGFLC. Note: *NL*: negative large, *NS*: negative small, *ZE*: zero, *PS*: positive small, *PL*: positive large.



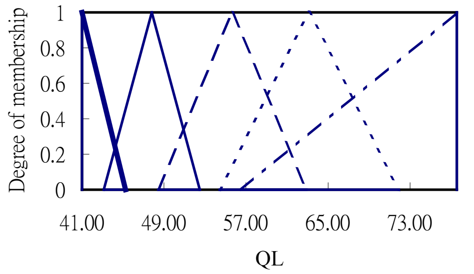
(a1)



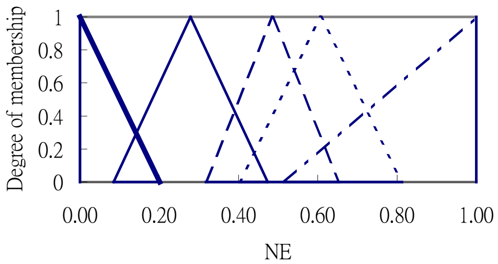
(b1)



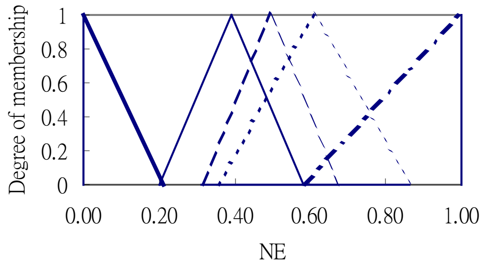
(a2)



(b2)

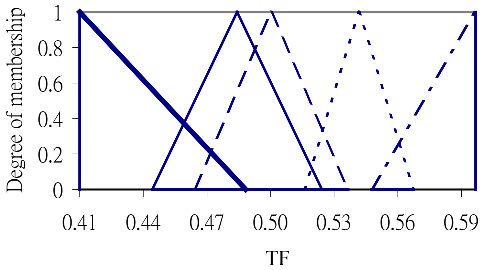


(a3)

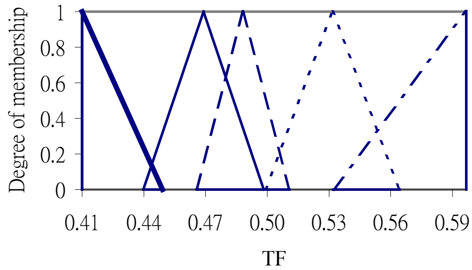


(b3)

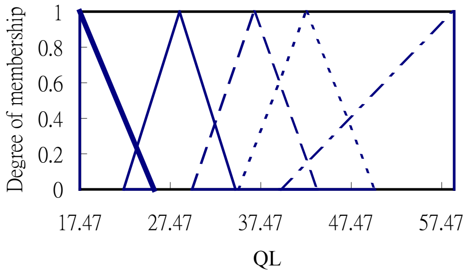
Figure 4-6 Tuned membership functions for green extension strategy of the exemplified example at an isolated intersection: (a1) *TF* by GFLC, (b1) *TF* by AGFLC, (a2) *QL* by GFLC, (b2) *QL* by AGFLC, (a3) *NE* by GFLC, (b3) *NE* by AGFLC.



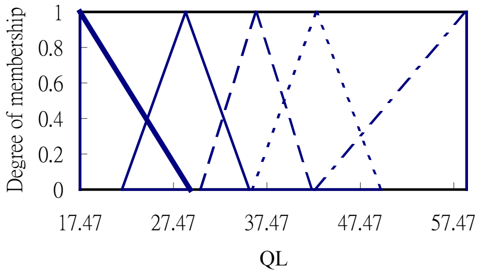
(c1)



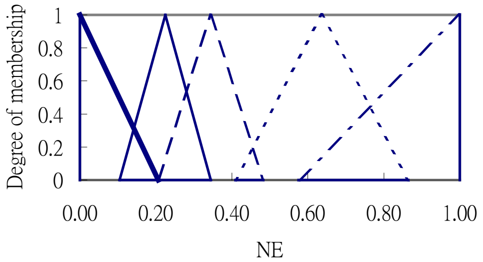
(d1)



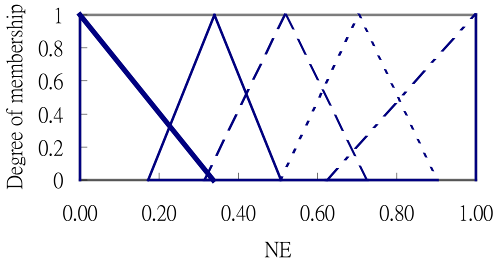
(c2)



(d2)



(c3)



(d3)

Figure 4-7 Tuned membership functions for red truncation strategy of the exemplified example at an isolated intersection: (c1) *TF* by GFLC, (d1) *TF* by AGFLC, (c2) *QL* by GFLC, (d2) *QL* by AGFLC, (c3) *NE* by GFLC, (d3) *NE* by AGFLC.

4.1.3 Comparisons

To investigate the performance of the proposed GFLC and AGFLC models, pre-timed signal without TPS and unconditional TPS are also simulated with the same traffic data. Table 4.2 shows the simulation results of green extension and red truncation, respectively. As comparing to the pre-timed signal, the AGFLC can curtail *TPD* by 8.17% and 13.20% in green extension and red truncation, respectively, while the GFLC can reduce *TPD* by 8.11% and 13.01%. Unconditional TPS can curtail *TPD* by 3.97% in green extension; however, it increases to more than six times of *TPD* when implementing red truncation due to incredible increase of person delay to other vehicles. The results indicate that the proposed two conditional TPS approaches perform better than unconditional TPS. Moreover, the AGFLC performs even better than GFLC. In terms of bus person delay, unconditional TPS curtails person delay by 20.69% in green extension and 52.75% in red truncation. The red truncation strategy could curtail a larger person delay to buses due to a large deduction of red time of arriving buses. The GFLC and AGFLC could curtail bus person delay by 26.28%~28.41% in green extension and red truncation strategies at the expense of slightly increasing person delay of other vehicles as green extension strategy is implemented. Furthermore, the unconditional TPS would greatly increases vehicle delays of the competing approaches especially in red truncation strategy while the GFLC and AGFLC models would take those impacts into consideration when providing the priority to the buses.

Table 4.2 Comparisons of different TPS models (the exemplified example at an isolated intersection)

TPS Strategy	Types of Vehicles	Without TPS	With TPS		
			Unconditional	Conditional	
				GFLC	AGFLC
Green Extension	Buses	563.2	446.7 (-20.69%)	415.2 (-26.28%)	410.4 (-27.13%)
	Benefit cars (1)	419.8	392.3 (-6.55%)	403.2 (-3.95%)	399.4 (-4.86%)
	Impact veh. (2)	487.0	572.7 (17.60%)	532.4 (9.32%)	540.1 (10.90%)
	(1)+(2)	906.8	965.0 (6.42%)	935.6 (3.18%)	939.5 (3.61%)
	All vehicles	1470.0	1411.7 (-3.97%)	1350.8 (-8.11%)	1349.9 (-8.17%)
Red Truncation	Buses	563.2	266.1 (-52.75%)	403.2 (-28.41%)	414.7 (-26.37%)
	Benefit cars (1)	419.8	234.2 (-44.21%)	333.2 (-20.63%)	339.7 (-19.08%)
	Impact veh. (2)	487.0	10763.1 (2111%)	542.3 (11.4%)	521.6 (7.10%)
	(1)+(2)	906.8	10997.3 (1112%)	875.5 (-3.45%)	861.3 (-5.02%)
	All vehicles	1470.0	11263.4 (666%)	1278.7 (-13.01%)	1276.0 (-13.20%)

Note: The unit of person delay is person-hour. Figures in parenthesis represent the percentages of person delay difference in comparing to that of without TPS model. Benefit cars: the vehicles except buses in the TPS direction. Impact veh.: the vehicles in the competitive direction.

During the ten-hour traffic simulation, pre-timed signal progresses 231 cycles; unconditional TPS, GFLC and AGFLC progress 216, 221, and 220 cycles in green extension and 260, 246, and 244 cycles in red truncation, respectively. The green extension and red truncation time of the first 100 cycles are depicted in Figures 4-8 and 4-9. As anticipated, unconditional TPS has longer green time and shorter red time because it gives priority to approaching buses without any restriction.

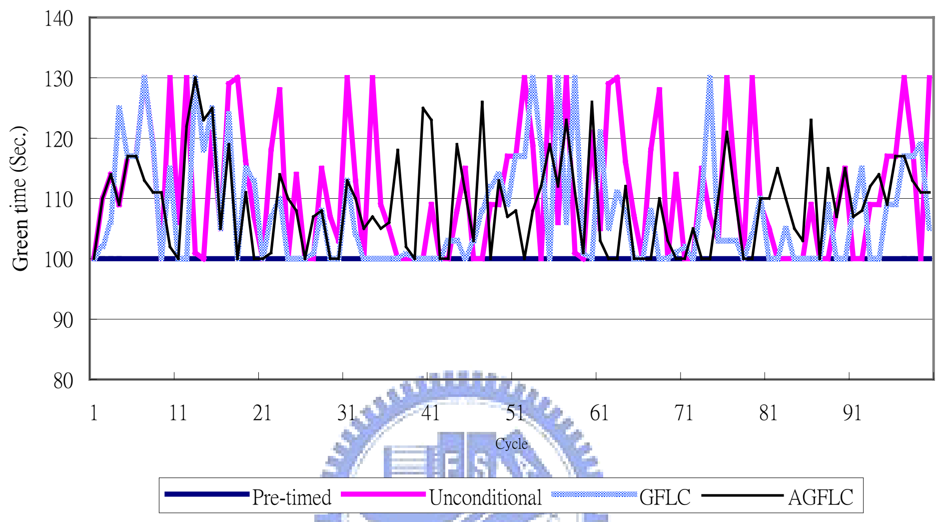


Figure 4-8 Green time of different TPS models with green extension strategy of the exemplified example at an isolated intersection.

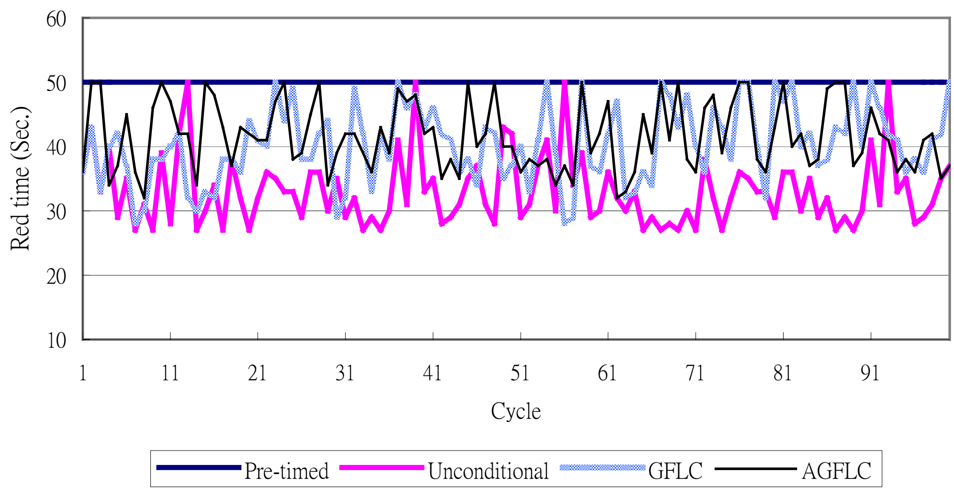


Figure 4-9 Red time of different TPS models with red truncation strategy of the exemplified example at an isolated intersection.

4.1.4 Sensitivity Analyses

To examine the robustness of the proposed models, sensitivity analyses on various traffic scenarios and bus loading factors are conducted. Traffic flow rates increase by 20% (called high traffic scenario) and decrease by 20% (called low traffic scenario) and average bus loading factors are varied as 20, 30, 50, and 60 persons per bus. Table 4.3 shows the simulation results of green extension and red truncation for various traffic scenarios and Figure 4-10 shows the *TPD* comparisons of green extension strategy. When implementing green extension, as comparing to the pre-timed signal, the AGFLC can curtail *TPD* by 6.16%~12.34%, while the GFLC can reduce *TPD* by 5.98%~12.27%. The unconditional TPS can only reduce *TPD* by 3.97%~10.11% and even increase *TPD* by 63.98% under high traffic. Note that both unconditional TPS and conditional TPS (including GFLC and AGFLC) perform better in low traffic than in high traffic. These results reveal that the AGFLC outperforms in all scenarios, followed by the GFLC. When implementing red truncation, similar results can be obtained. Moreover, focusing on the difference between green extension and red truncation, with the increase of traffic, green extension would perform better than red truncation due to the fact that the latter would cause a larger impact on the competing approaches as traffic increases. This indicates the advantage of implementing green extension under high traffic and red truncation under low traffic.

Furthermore, Table 4.4 shows the person delay of green extension and red truncation for different average bus loading factors and Figure 4-11 shows the *TPD* comparisons of green extension strategy. As comparing to the pre-timed signal without TPS, the AGFLC can curtail the largest percentage of *TPD*, followed by the GFLC under both green extension and red truncation. Unconditional TPS even increases *TPD* when implementing red truncation. As expected, when the bus loading factor gets higher, the effectiveness in reducing *TPD* would be further enhanced for all unconditional and conditional TPS examined. It reveals the advantage of implementing TPS in a high bus loading factor situation.

Table 4.3 Comparisons of different TPS models under various traffic scenarios (the exemplified example at an isolated intersection)

TPS Strategy	Traffic Scenarios	Types of Vehicles	Without TPS	With TPS: Unconditional	With TPS: Conditional GFLC	With TPS: Conditional AGFLC
Green Extension	High Traffic	Buses	685.9	488.2 (-28.82%)	560.1 (-18.34%)	556.7 (-18.84%)
		Other vehicles	1824.8	3628.8 (98.86%)	1800.4 (-1.34%)	1799.3 (-1.40%)
		All vehicles	2510.7	4117.0 (63.98%)	2360.5 (-5.98%)	2356.0 (-6.16%)
	Medium Traffic	Buses	563.2	446.7 (-20.69%)	415.2 (-26.28%)	410.4 (-27.13%)
		Other vehicles	906.8	965.0 (6.42%)	935.6 (3.18%)	939.5 (3.61%)
		All vehicles	1470.0	1411.7 (-3.97%)	1350.8 (-8.11%)	1349.9 (-8.17%)
	Low Traffic	Buses	465.6	334.0 (-28.26%)	321.0 (-31.06%)	320.3 (-31.21%)
		Other vehicles	522.3	554.0 (6.07%)	545.7 (4.48%)	545.7 (4.48%)
		All vehicles	987.9	888.0 (-10.11%)	866.7 (-12.27%)	866.0 (-12.34%)
Red Truncation	High Traffic	Buses	685.9	280.9 (-59.05%)	625.9 (-8.75%)	621.9 (-9.33%)
		Other vehicles	1824.8	68697.0 (3664%)	1791.4 (-1.83%)	1794.5 (-1.66%)
		All vehicles	2510.7	68977.9 (2647%)	2417.3 (-3.72%)	2416.4 (-3.76%)
	Medium Traffic	Buses	563.2	266.1 (-52.75%)	403.2 (-28.41%)	414.7 (-26.37%)
		Other vehicles	906.8	10997.3 (1112%)	875.5 (-3.45%)	861.3 (-5.02%)
		All vehicles	1470.0	11263.4 (666%)	1278.7 (-13.01%)	1276.0 (-13.20%)
	Low Traffic	Buses	465.6	377.1 (-19.01%)	346.0 (-25.69%)	343.6 (-26.20%)
		Other vehicles	522.3	486.5 (-6.85%)	485.0 (-7.14%)	485.9 (-6.97%)
		All vehicles	987.9	863.6 (-12.58%)	831.0 (-15.88%)	829.5 (-16.03%)

Note: The unit of person delay is person-hour. Figures in parenthesis represent the percentages of person delay difference in comparing to that of without TPS model.

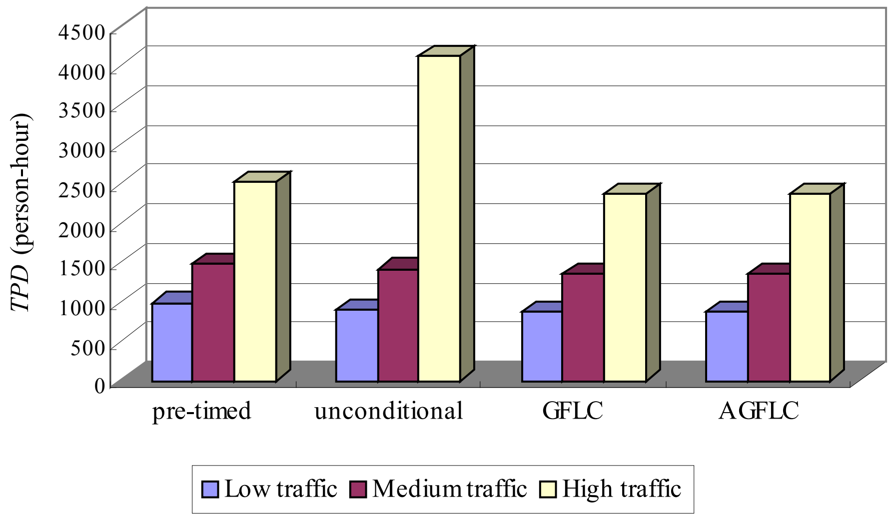


Figure 4-10 *TPD* Comparisons for different TPS models under various traffic scenarios (the exemplified example at an isolated intersection)

Table 4.4 Comparisons of different TPS models under various bus loading factors (the exemplified example at an isolated intersection)

TPS Strategy	Loading Factor	Types of Vehicles	Without TPS	With TPS: Unconditional	With TPS: Conditional GFLC	With TPS: Conditional AGFLC
Green Extension	20	Buses	281.6	223.4 (-20.69%	205.8 (-26.92%)	205.7 (-26.95%)
		Other vehicles	906.8	965.0 (6.42%)	935.5 (3.16%)	935.3 (3.14%)
		All vehicles	1188.4	1188.4 (0.00%)	1141.3 (-3.96%)	1141.0 (-3.99%)
	30	Buses	422.4	335.0 (-20.69%	310.7 (-26.44%)	308.2 (-27.04%)
		Other vehicles	906.8	965.0 (6.42%)	937.2 (3.35%)	938.7 (3.52%)
		All vehicles	1329.2	1300.0 (-2.19%)	1247.9 (-6.12%)	1246.9 (-6.19%)
	40	Buses	563.2	446.7 (-20.69%	415.2 (-26.28%)	410.4 (-27.13%)
		Other vehicles	906.8	965.0 (6.42%)	935.6 (3.18%)	939.5 (3.61%)
		All vehicles	1470.0	1411.7 (-3.97%)	1350.8 (-8.11%)	1349.9 (-8.17%)
	50	Buses	704.0	558.4 (-20.69%	513.3 (-27.09%)	503.8 (-28.44%)
		Other vehicles	906.8	965.0 (6.42%)	936.5 (3.28%)	937.4 (3.37%)
		All vehicles	1610.8	1523.4 (-5.43%)	1449.8 (-10.00%)	1441.2 (-10.53%)
	60	Buses	844.8	670.1 (-20.69%	620.0 (-26.61%)	610.3 (-27.76%)
		Other vehicles	906.8	965.0 (6.42%)	937.5 (3.39%)	941.3 (3.80%)
		All vehicles	1751.6	1635.1 (-6.65%)	1557.5 (-11.08%)	1551.6 (-11.42%)
Red Truncation	20	Buses	281.6	133.1 (-52.75%	216.4 (-23.15%)	213.1 (-24.33%)
		Other vehicles	906.8	10997.3 (1112%)	855.5 (-5.66%)	858.6 (-5.32%)
		All vehicles	1188.4	11130.4 (836%)	1071.9 (-9.80%)	1071.7 (-9.82%)
	30	Buses	422.4	199.6 (-52.75%	318.5 (-24.60%)	301.6 (-28.60%)
		Other vehicles	906.8	10997.3 (1112%)	858.9 (-5.28%)	875.5 (-3.45%)
		All vehicles	1329.2	11196.9 (742%)	1177.4 (-11.42%)	1177.1 (-11.44%)
	40	Buses	563.2	266.1 (-52.75%	403.2 (-28.41%)	414.7 (-26.37%)
		Other vehicles	906.8	10997.3 (1112%)	875.5 (-3.45%)	861.3 (-5.02%)
		All vehicles	1470.0	11263.4 (666%)	1278.7 (-13.01%)	1276.0 (-13.20%)
	50	Buses	704.0	332.6 (-52.75%	504.9 (-28.28%)	505.8 (-28.15%)
		Other vehicles	906.8	10997.3 (1112%)	881.1 (-2.83%)	877.9 (-3.19%)
		All vehicles	1610.8	11329.9 (603%)	1386.0 (-13.96%)	1383.7 (-14.10%)
	60	Buses	844.8	399.2 (-52.75%	608.9 (-27.92%)	602.3 (-28.71%)
		Other vehicles	906.8	10997.3 (1112%)	878.9 (-3.08%)	878.5 (-3.12%)
		All vehicles	1751.6	11396.5 (550%)	1487.8 (-15.06%)	1480.8 (-15.46%)

Note: The unit of person delay is person-hour. Figures in parenthesis represent the percentages of person delay difference in comparing to that of without TPS model.

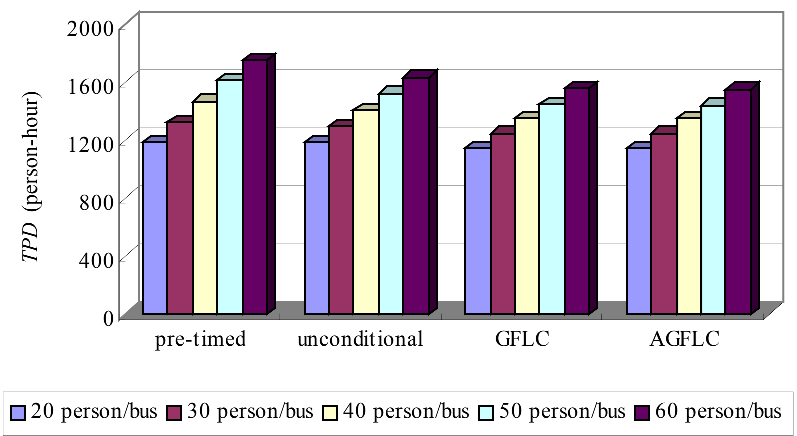


Figure 4-11 *TPD* Comparisons for different TPS models under various bus loading factors (the exemplified example at an isolated intersection)

4.2 Field Case

4.2.1 Data and Parameters

For investigating the applicability of the GFLC and AGFLC, a field case is conducted at the intersection of Hsin-I road and Ta-An road in Taipei city. Figure 4-12 demonstrates the basic configuration of this intersection. There are a total of 6 lanes, containing 2 bus-exclusive lanes on Hsin-I road and 2 lanes on Ta-An road. The traffic data of bus, car and motorcycle are collected by video cameras from 4:00 pm to 5:00 pm and then transformed into 5-minute traffic flow data as shown in Figure 4-13. The current signal phase of this intersection is pretimed with green 140 seconds and red 60 seconds in the Hsin-I approaches.

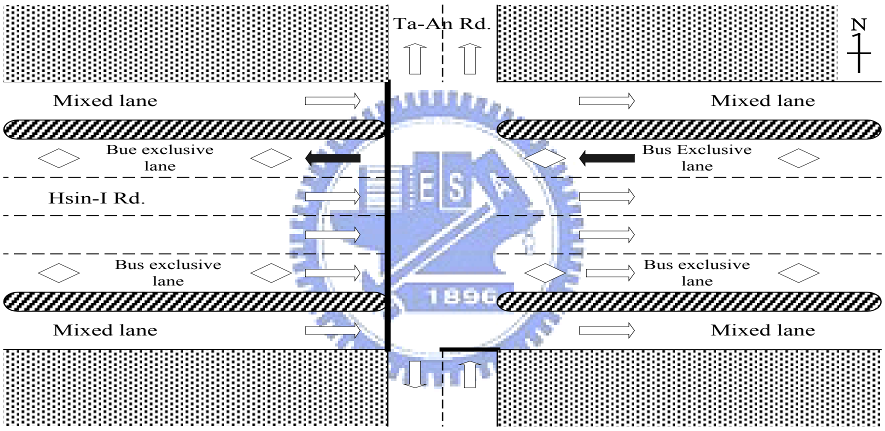


Figure 4-12 Configuration of the field case at an isolated intersection.

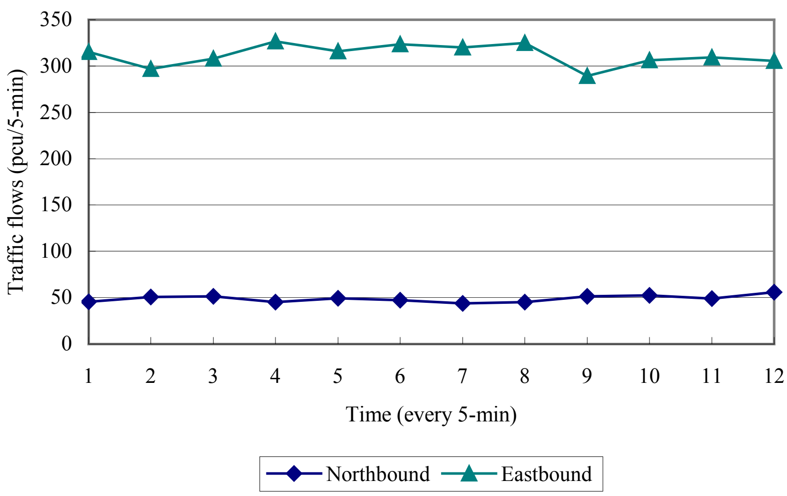


Figure 4-13 Observed flow rates of the field case at an isolated field intersection.

The parameters of GA and ACO algorithms, like population size, crossover rate, mutation rate, a, h, δ, ε, NE_t, α, β, ξ, ρ, q_0, θ_{i6}, τ^0, K, and t_{max} are set to be the same as those in the exemplified example. The predetermined rule table for ACO algorithm and average loading factors of private cars and buses are also assumed to be the same as those in the exemplified example. Referring to the current timing plan at the field intersection, the maximal and minimal green time is set as 170 seconds and 30 seconds, respectively.

4.2.2 Results

Table 4.5 shows the simulation results of this field case. Comparing to the current pre-timed signal timing plan without TPS, the AGFLC can curtail *TPD* by 52.01% and 54.80% in green extension and red truncation, respectively, while the GFLC can reduce *TPD* by 51.50% and 53.26% and unconditional TPS can curtail *TPD* by 47.91% and 34.07%. The results indicate that the implementation of three different TPS could have a significant improvement on the *TPD*. However, the AGFLC still outperforms, followed by the GFLC. When implement unconditional TPS, the performance of green extension strategy is superior to that of red truncation strategy. While when implement conditional TPS, the performances of green extension and red truncation strategies do not significantly differ. As expected, unconditional TPS curtails more person delay for buses than conditional TPS because the latter does not provide absolute priority treatment to buses.

Table 4.5 Comparisons of different TPS models (the field case at an isolated intersection)

TPS Strategy	Types of Vehicles	Current Timing (Without TPS)	With TPS		
			Unconditional	Conditional	
				GFLC	AGFLC
Green Extension	Buses	14.2	0.9 (-93.66%)	3.8 (-73.24%)	2.7 (-80.99%)
	Other vehicles	122.3	70.2 (-42.60%)	62.4 (-48.98%)	62.8 (-48.65%)
	All vehicles	136.5	71.1 (-47.91%)	66.2 (-51.50%)	65.5 (-52.01%)
Red Truncation	Buses	14.2	0.7 (-95.07%)	3.5 (-75.35%)	3.1 (-78.17%)
	Other vehicles	122.3	89.3 (-26.98%)	60.3 (-50.70%)	58.6 (-52.09%)
	All vehicles	136.5	90.0 (-34.07%)	63.8 (-53.26%)	61.7 (-54.80%)

Note: The unit of person delay is person-hour. Figures in parenthesis represent the percentages of person delay difference in comparing to that of without TPS model.