Investigation of Optimal Time to Change Arterial Traffic Signal-Timing Plan

BASIM K. JREW and PETER S. PARSONSON

ABSTRACT

The objective of this study was to use several off-line computer programs to provide a technique for determining the optimal afternoon time during which to change the off-peak timing plan to the peak-period timing plan for a particular Atlanta arterial. The study made use of PASSER II-80 (an arterial-optimization model), TRANSYT-7F (a model for optimizing arterials or grids), and SOAP/M (an intersection-optimization model). An attempt to establish different optimal timing plans for the off-peak hour (1:00 to 2:00 p.m.) and the peak hour (5:00 to 6:00 p.m.) using PASSER was unsuccessful because it was found that both hours required the same cycle length. The TRANSYT optimization program produced different cycle lengths for the two hours. The authors adjusted these cycle lengths to 85 sec for the off-peak hour and 115 sec for the peak hour so that there would be a clear superiority of one over the other at each of the two times of day. Twenty TRANSYT simulation runs were then performed forward in time, from 1:00 to 6:00 p.m., by using the off-peak optimal timing plan and the volumes for each 15-min period. Another 20 TRANSYT simulation runs were performed backward in time, from 6:00 to 1:00 p.m., by using the peak-hour optimal timing plan and the volumes for each 15-min period. The two plots of performance index versus time of day intersected at 4:15 p.m., the optimal time to change plans. The TRANSYT-oriented procedure involved considerable effort and computer time. It was theorized that the TRANSYT procedure might be replaced by a relatively simple SOAP/M analysis of only the critical intersection. However, it was found that at all times during the afternoon the off-peak cycle length had a lower traffic performance index; therefore, the SOAP/M analysis failed to produce an optimal time to change the plan.

The nature of the study was to use several off-line computer programs to determine the optimal afternoon time during which to change from the off-peak timing plan to the peak-period timing plan.

The City of Atlanta is expanding the city's existing computerized traffic control system to include signals on Piedmont Road. The seven intersections from Lakeshore Drive to E. Wesley Road were selected for the study. This study was undertaken to assist the City of Atlanta in implementing optimal signal-timing plans for both off-peak and peak periods, and was intended to develop a technique for changing the timing plan from one to another during various periods of the day.

SUMMARY OF PROCEDURE

The off-line computer programs PASSER II-80, TRANSYT-7F, and SOAP/M were applied to the Piedmont Road study route.

PASSER II-80 is used to determine optimum progression along an arterial street (1). This program can optimize the cycle length. PASSER can also optimize phasing, but the city preferred that no attempt be made to change the phasing from that now existing on Piedmont Road. It does not change with time of day.

TRANSYT-7F is used to optimize a coordinated signal system to reduce stops, delay, and fuel consumption (2). The program optimizes phase lengths and offsets of the coordinated traffic signals in order to minimize a traffic performance index (PI), which is a linear combination of stops and delay. The program consists of the following two traffic models: first, a simulation model takes preliminary signal timings and determines the before PI; then an optimization model makes changes to the signal timings until the PI is minimized.

SOAP/M is a microcomputer version of the Signal Operation and Analysis Program (3). The program is widely used to evaluate and optimize intersection performance in terms of stops, delay, and fuel consumption.

The research plan was first to use PASSER to determine the optimal timing plan for off-peak traffic from 1:00 to 2:00 p.m. and the optimal plan for peak-hour traffic from 5:00 to 6:00 p.m. It was expected that the two plans would be different, especially in cycle length, because of the heavier traffic volumes during the peak hour.

Next, it was intended that the off-peak plan be used as input to the TRANSYT-7F program and that a simulation run using the traffic volumes for each 15-min interval be performed. The optimal off-peak plan (1:00 to 2:00 p.m.) would be run forward in time, that is, using the increasing volumes from 1:00 to 6:00 p.m. A plot would be prepared for PI versus time of day. Then, the optimal peak-hour plan (5:00 to 6:00 p.m.) would be run backward in time, that is, using the decreasing volumes from 6:00 to 1:00 p.m., and a second curve would be plotted. The intersection of the two curves was to be the optimal time during which to change from one plan to another during the afternoon.

School of Civil Engineering, Georgia Institute of Technology, Atlanta, Ga. 30332.

Finally, SOAP/M was to be run forward and backward in a similar fashion, for only the critical intersection; it was hoped that this simpler procedure would point to approximately the same time of day to change plans as was indicated by TRANSYT.

The results did not completely meet expectations. First, the PASSER runs pointed to a single optimal cycle length for both the off-peak hour and the peak hour. Because the purpose of the project was to investigate the change from one plan to a different one, the first step was repeated using the TRANSYT program. Two different optimal cycle lengths resulted, but the PI of the shorter was not significantly superior to that of the longer during the off-peak hour. It was decided to increase the longer cycle length; thus shorter cycle length was significantly better than the longer one during the off-peak hour and the longer was definitely better than the shorter during the peak hour. This set of timing plans appeared to furnish a base for further steps to determine the optimal time to change from one timing plan to another.

As planned, 20 TRANSYT simulation runs were then performed forward in time from 1:00 to 6:00 p.m. by using the off-peak plan. The volumes for each run were the 15-min values for that time of day multiplied by 4 to give equivalent hourly volumes. Another 20 runs were performed backward in time from 6:00 to 1:00 p.m. by using the peak-hour plan. The two curves of PI versus time of day crossed at 4:15 p.m., a reasonable outcome.

SOAP/M was used to determine stops and delay at the critical intersection of the arterial system. Ten optimization runs were performed using the off-peak cycle length at 30-min intervals from 1:00 to 6:00 p.m. The volume for each run was the 30-min volume for that time of day multiplied by 2 to give an equivalent hourly volume. Another 10 optimization runs were performed by using the peak-period cycle length at 30-min intervals from 6:00 to 1:00 p.m. Again, the volumes used were for each 30-min time of day. In an attempt to show the optimal time to change plans, a plot of PI versus the time of day was prepared. It was hoped that this approach could eliminate the need to run TRANSYT-7F, thereby reducing the analysis effort. It turned out that a single plan was optimal for the entire period from 1:00 to 6:00 p.m.; thus, in this study the critical intersection could not successfully represent the arterial for this purpose.

DATA COLLECTION

The study procedure included data collection, which is common to all of the programs, data preparation, and network coding of the input data for each individual program. The traffic data were collected in the afternoon during off-peak and peak periods (1:00 to 6:00 p.m.) at all of the seven intersections.

Five major types of data were collected for use in the three programs. Each of these types will be described.

Network Data

The field measurements and the node-link identification scheme are shown in Figure 1. The sketch shows the geometrics of each intersection, number of approach lanes, lane width, node number, link number, and the link distances.

Traffic Volume Data

Two types of traffic volume data were needed: (a) the city-furnished 24-hr machine-count volume data used to determine the time period during which a given timing plan should be in operation; and (b) the turning movement volumes for the approaches to each signalized intersection, obtained every 15 min from 1:00 to 6:00 p.m.

Saturation Flow Data

Headway samples were collected to calculate saturation flow rate for each major link, following standard TRANSYT-7F procedures (2). When a signal turned green, the headway was sampled beginning with the third vehicle of the queue as the platoon discharged.

Speed Data

Both the floating-car method and a radar gun were used to collect speed data at the major links in the network system. Free-flowing traffic was sampled; speeds were not affected by the downstream signal.

Signal Phasing

The existing phase sequences were inventoried and used as input to the computer programs. On Piedmont Road, the phasing does not change with time of day. The phasing was held constant in all computer runs; PASSER was not allowed to optimize the phasing.

Much of the input data prepared for the PASSER II-80 program is similar to that prepared for TRANSYT-7F. Intersection distances, progression speeds, allowable cycle lengths, turning movement volumes, saturation flow rate, and minimum phase duration are used in both programs. The link input volume, lost time, and green extension data were prepared specifically for the TRANSYT-7F program.

FINDINGS

The findings of the study were based on the output of the three programs mentioned earlier.

Passer II-80 Output Results

The output of the PASSER II-80 program consists of three printed reports and printer plots. The first report is simply a listing of the input data as submitted to the computer. The second report includes guidelines for minimum and maximum cycle lengths for each intersection. The third report presents the best solution for signal timing at each intersection in the coordinated system. The printer plot of the time-space diagram shows the uniform bandwidth and the speed of the progression for both directions.

An evaluation of the cycle length was performed to determine the best solution optimum progressions for the off-peak (1:00 to 2:00 p.m.) and peak periods (5:00 to 6:00 p.m.) for Piedmont Road. The cycle length ranged from 60 to 120 sec for off-peak-period evaluation and from 100 to 120 sec for peak-period evaluation. The smallest permissible cycle length was selected as 85 percent of the largest individual cycle length (1). The maximum cycle length was taken as 120 sec (1).

Seven PASSER runs were performed to select the off-peak cycle length. The results are given in Table 1. The best solution for the off-peak cycle length was found to be 110 sec with a 39 sec uniform bandwidth for both directions and an average arterial delay of 15.35 sec per vehicle. The progression speeds were found to be 41 mph for Direction A (northbound) and 42 mph for Direction B (south-

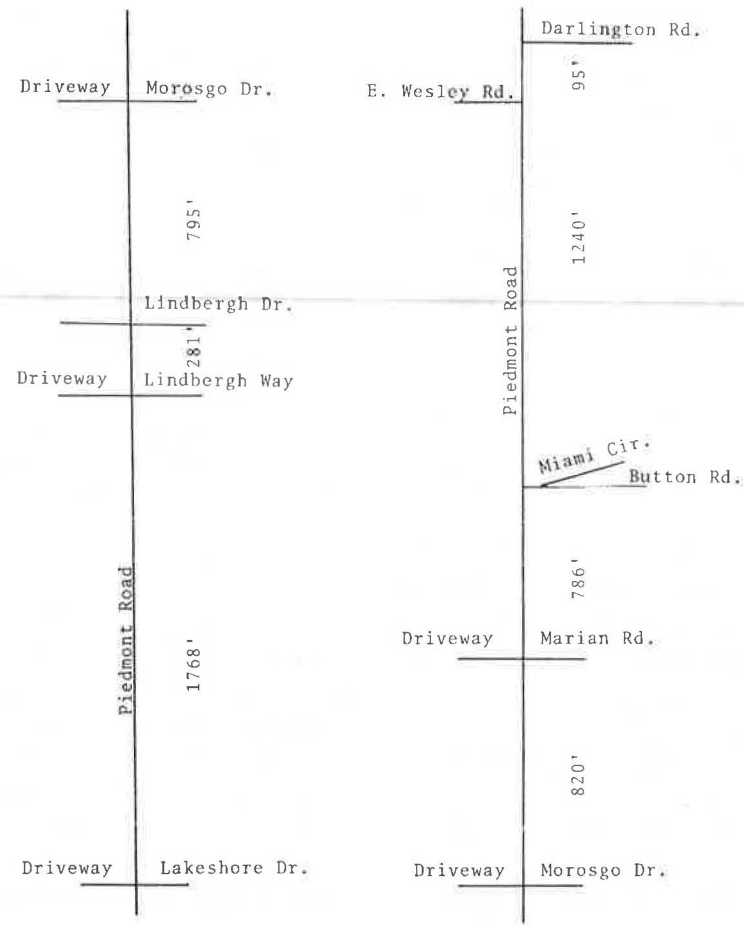

FIGURE 1 Field measurements and the node-link identification scheme.

bound). The results indicated an increase in the average delay and the percentage of efficiency as the cycle length increased.

Another two PASSER runs were performed to permit evaluation of the peak-period cycle length. The resulting outputs are given in Table 2 as Runs 1 and 2. The best solution for the peak period was found to be 110 sec with a 44 sec uniform bandwidth in both directions. The average arterial delay was 16.66 sec per vehicle. The progression speeds were 40 mph for the northbound direction and 41 mph for the southbound direction. (Run No. 3 in Table 2 is explained later in the paper.) The two tables show that the same cycle length was selected for both periods of time, but with different signal-timing plans and different speeds of progression. The off-peak signal-timing plan provided a higher speed, a lower percentage of efficiency, and lower average delay than did the peak signal timing plan.

That PASSER did not select different cycle lengths for the two traffic-analysis periods presented an obstacle to further work to determine the optimal time to change timing plans. Therefore, cycle lengths were investigated further using TRANSYT-7F.

TRANSYT-7F Output Results

Five basic outputs are available from the TRANSYT-7F program:

- Input data report
- Traffic performance table
- Flow profile plots
- Signal-timing table
- Time-space diagram

TABLE 1 PASSER II-80 Output Results for Off-Peak Hour

			Band A		Band B				
Run No.	Cycle Range (sec)	Best Solution (sec)	Time (sec)	Speed (mph)	Time (sec)	Speed (mph)	Efficiency (%)	Total Delay (sec)	Average Delay (sec/veh)
1	60-75	75	17	44	17	45	24	298,163.93	12.51
2	60-80	80	21	44	21	45	27	301,086.61	12.63
3	60-85	85	25	44	25	45	29	306,706.53	12.87
4	60-90	90	28	44	28	45	32	319,358.76	13.40
5	60-95	95	31	44	31	45	34	333,242.40	13.98
6	60-110	110	39	41	39	42	36	365,822.66	15.35
7	60-120	110	39	41	39	42	36	365,822.66	15.35

TABLE 2 PASSER II-80 Output Results for Peak Hour

			Band A		Band B				
Run No.	Cycle Range (sec)	Best Solution (sec)	Time (sec)	Speed (mph)	Time (sec)	Speed (mph)	Efficiency (%)	Total Delay (sec)	Average Delay (sec/veh)
1	100-110	110	44	40	44	41	40	518,716.33	16.66
2	100-120	110	44	40	44	41	40	518,716.33	16.66
3	115-120[a]	115	46	40	46	41	40	564,147.03	18.12

[a]An additional run to provide a timing plan for C = 115 sec was needed for TRANSYT-7F.

The TRANSYT-7F program was used in two stages. During the first stage, the optimal cycle lengths for the off-peak (1:00 to 2:00 p.m.) timing plan and the peak (5:00 to 6:00 p.m.) timing plan were determined. During the second stage, the optimal time to change from one timing plan to another was determined, considering the entire period from 1:00 to 6:00 p.m.

First-Stage Evaluation

The optimization process of the TRANSYT-7F program was performed for cycle lengths of from 75 to 120 sec. Ten runs were performed for the off-peak hourly volume (1:00 to 2:00 p.m.) and another 10 runs for the peak hourly volume (5:00 to 6:00 p.m.). The output timing data of PASSER II were used as input timing for all of the TRANSYT-7F runs.

Tables 3 and 4 give summaries of the TRANSYT-7F output. The optimal cycle length for each hour was selected to be the one with the lowest PI.

Tables 3 and 4 show that the cycle length that produced the lowest PI was 85 sec for the off-peak hour and 100 sec for the peak hour. The 85-sec cycle produced a PI of 115.94 during the off-peak hour and a higher value, 195.10, during the peak hour. The 100-sec cycle produced a PI of 170.48 during the peak hour. The PI of this cycle was only 117.44 during the off-peak hour.

A plot of PI versus time of day for the 85-sec and 100-sec cycles is shown in Figure 2. This figure shows an insignificant (1.3 percent) difference in PIs during the off-peak hour and a 13 percent difference in PIs during the peak hour. The 100-sec cycle length probably would perform better than the 85-sec cycle length from 2:00 to 5:30 p.m. Therefore, Figure 2 does not indicate that there would be any point in additional research to determine an optimal time to change from one timing plan to another.

This difficulty was sidestepped by replacing the 100-sec solution for the peak hour with the 115-sec solution. Looking at Table 4, it can be seen that the 115-sec cycle length produces the second lowest PI (172.23) during the peak hour; therefore, it was reasonable to select it.

The 115-sec cycle length was plotted along with the 85-sec off-peak cycle length in Figure 3. This figure shows significant differences in PIs during both the off-peak hour and the peak hour. The differences are seen to be 7 and 12 percent, respectively. Figure 3 indicates a basis for this project

TABLE 3 TRANSYT-7F Output Results for Off-Peak Period Cycle-Length Evaluation

Run No.	Cycle Length (sec)	Total Arterial Delay (veh-hr/hr)	Average Arterial Delay[a] (sec/veh)	Total Uniform Stops (veh/hr)	Fuel Consumption (gal/hr)	Performance Index
1	75	55.205	8.61	9,165.0	259.63	118.85
2	80	56.431	8.80	8,643.6	252.11	116.46
3	85	56.583	8.82	8,547.5	251.2	115.94
4	90	60.851	9.49	8,442.3	250.7	119.48
5	95	62.707	9.78	7,897.5	243.96	117.55
6	100	63.999	9.98	7,695.4	241.61	117.44
7	105	66.832	10.42	7,661.1	242.69	120.03
8	110	72.661	11.33	7,530.0	243.06	124.95
9	115	72.759	11.35	7,465.1	242.48	124.60
10	120	72.009	11.85	7,200.0	239.17	126.01

[a]Average arterial delay = [total arterial delay (veh-hr/hr) x 3,600 sec] ÷ [total arterial flow (vph)]. Total arterial flow = 23,086 vph = sum of link flows at the seven nodes.

TABLE 4 TRANSYT-7F Output Results for Peak-Period Cycle-Length Evaluation

Run No.	Cycle Length (sec)	Total Arterial Delay (veh-hr/hr)	Average Arterial Delay[a] (sec/veh)	Total Uniform Stops (veh/hr)	Fuel Consumption (gal/hr)	Performance Index
1	75	117.462	13.91	14,672.5	410.25	219.36
2	80	104.401	12.36	14,183.4	397.32	202.90
3	85	97.577	11.55	14,043.5	392.07	195.10
4	90	95.236	11.28	12,442.7	367.05	181.64
5	95	92.488	10.95	11,869.3	357.84	174.91
6	100	90.310	10.69	11,544.2	352.56	170.48
7	105	92.220	10.92	11,537.8	353.32	172.34
8	110	93.646	11.09	11,388.6	352.76	172.73
9	115	96.482	11.43	10,907.4	347.18	172.23
10	120	99.779	11.82	10,892.5	348.06	175.42

[a]Average arterial delay = [total arterial delay (veh-hr/hr) x 3,600 sec] ÷ [total arterial flow (vph)]. Total arterial flow = 23,086 vph; 30,400 vph = sum of link flows at the seven nodes.

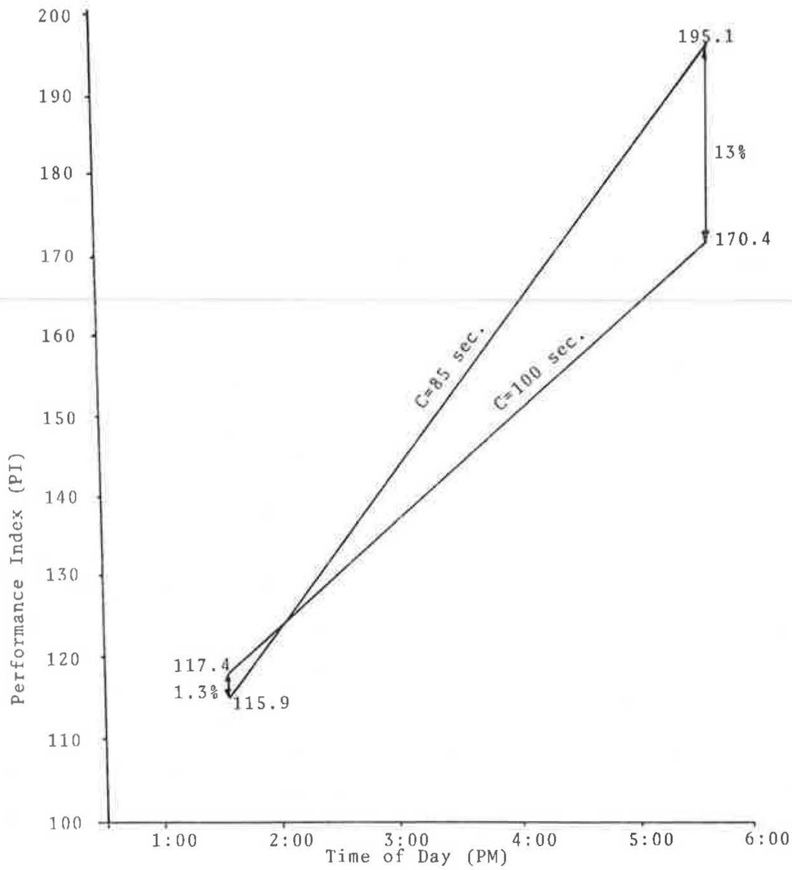

FIGURE 2 Comparison of 85-sec and 100-sec cycle lengths.

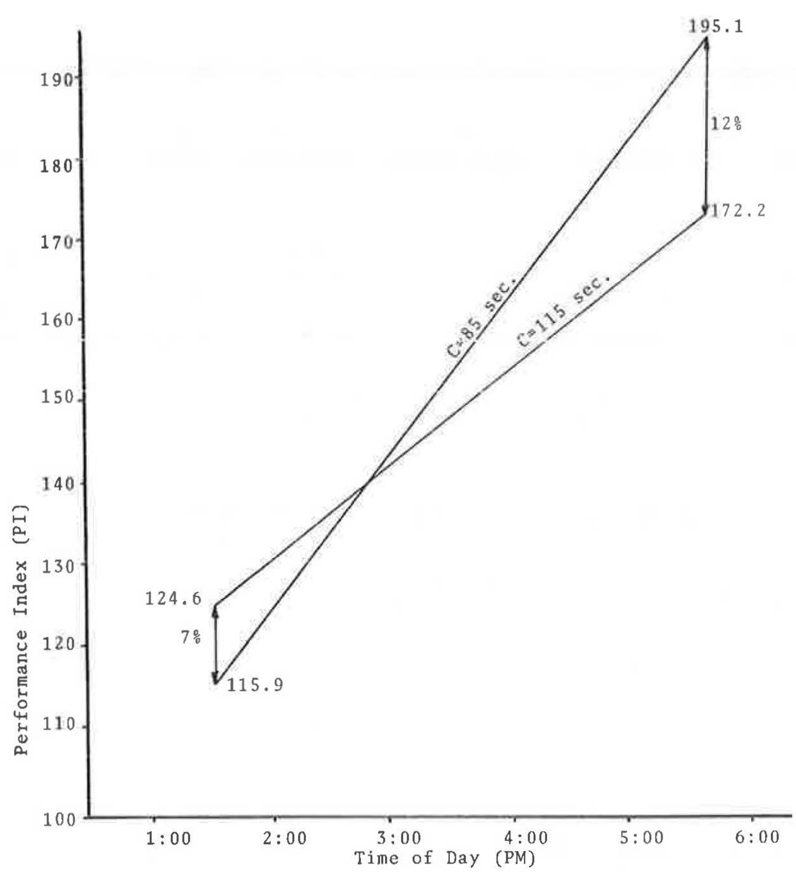

FIGURE 3 Comparison of 85-sec and 115-sec cycle lengths.

to continue its research to determine an optimal time to change from one timing plan to another. Therefore, the final cycle lengths selected were 85 sec for the off-peak hour and 115 sec for the peak hour.

Figures 2 and 3 can easily be misunderstood. The plotted points pertain to conditions from 1:00 to 2:00 p.m. and from 5:00 to 6:00 p.m., not from 2:00 to 5:00 p.m. as well. The straight lines connecting the points do not represent an assertion that the PI varies linearly as the afternoon progresses. (That subject is taken up later in the paper.) Neither does Figure 3 mean that, for example, the timing plan should be changed at 2:45 p.m.; that determination is made later, in a different way. The meaning of Figure 3 is only that the shorter cycle length was significantly better than the longer one during the off-peak hour and that the longer cycle was definitely better than the shorter one during the peak hour. Therefore, the researchers were in a position to take additional steps to determine the optimal time to change from one timing plan to the other.

The PASSER-80-derived timing plan for an 85-sec cycle length was used as the input to the TRANSYT-7F simulation program as the initial run to develop the off-peak signal-timing plan. This simulation program produces measures of effectiveness (MOEs) that are not shown in a PASSER-II-80 output, such as total network delay, stops, and fuel consumption. The TRANSYT-7F optimization program was used to produce the final off-peak signal-timing plan. The results for both runs are given in Table 5. This table shows that TRANSYT optimization significantly reduced stops, delay, fuel consumption, and PI. The average delay was reduced by 9 percent, the total uniform stops were reduced by 13 percent, and the total fuel consumption was reduced by 7 percent; the PI was reduced by 11 percent.

TABLE 5 TRANSYT-7F Simulation and Optimization Runs for Off-Peak Timing Plan

	Average Delay (sec/veh)	Total Delay (veh-hr/hr)	Total Uniform Stops (veh/hr)	Total Fuel Consumption (gal/hr)	Performance Index
Initial run	9.73	62.368	9,808.2	270.71	130.48
Final run	8.83	56.583	8,547.5	251.2	115.94
Saving (%)	9	9	13	7	11

Note: C = 85 sec.

The same procedure was followed for the optimum cycle length of the peak hour. The input data were obtained by running PASSER for peak-hour volumes and C = 115 sec, as shown in Table 2, Run 3. Table 6 gives the results of the TRANSYT-7F initial run and the TRANSYT-7F final run for the peak hour. The results indicate a greater reduction in stops, delay, fuel consumption, and PI than was obtained for the off-peak hour. The TRANSYT optimization of signal settings during the peak hour produced a savings of 15 percent in average delay, 33 percent in total uniform stops, and 19 percent in fuel consumption; the PI was reduced by 24 percent.

TABLE 6 TRANSYT-7F Simulation and Optimization Runs for Peak Hour Timing Plan

	Average Delay (sec/veh)	Total Delay (veh-hr/hr)	Total Uniform Stops (veh/hr)	Total Fuel Consumption (gal/hr)	Performance Index
Initial run	13.42	113.293	16,175.4	430.07	225.62
Final run	11.43	96.482	10,907.4	347.18	172.23
Saving (%)	15	15	33	19	24

C = 115 sec.

Second-Stage Evaluation

The second stage of applying the TRANSYT-7F program was to use the optimum cycle lengths developed for the off-peak hour and for the peak hour to determine the optimal time to change plans.

Twenty simulation runs were performed for the off-peak optimum cycle length (C = 85 sec) at 15-min intervals from 1:00 to 6:00 p.m. Another 20 simulation runs were performed for the peak-hour optimum cycle length (C = 115 sec) at 15-min intervals from 6:00 to 1:00 p.m.

Table 7 gives the PI of each run for the off-peak and peak cycle lengths. For each 15-min period, the PIs resulting from the two cycle lengths were compared. The results indicated that the 85-sec cycle performed better during the off-peak period and that the 115-sec cycle performed better during the peak period. The results also indicated that during the off-peak period, the off-peak cycle length produced a maximum of 8 percent better PI than the peak cycle length; during the peak period, the peak cycle length produced a maximum of 11 percent better PI than the off-peak cycle length.

TABLE 7 TRANSYT-7F Performance Index Comparison

Time Period (p.m.)	C = 85 Sec Run No.	C = 85 Sec P.I.	C = 115 Sec Run No.	C = 115 Sec P.I.	Difference (%)
1:00–1:15	1	129.54	21	140.53	+8
1:15–1:30	2	129.65	22	139.97	+7
1:30–1:45	3	130.85	23	142.62	+8
1:45–2:00	4	130.14	24	141.05	+8
2:00–2:15	5	133.30	25	143.42	+7
2:15–2:30	6	135.89	26	144.62	+6
2:30–2:45	7	135.88	27	145.99	+7
2:45–3:00	8	139.85	28	149.25	+6
3:00–3:15	9	138.77	29	147.78	+6
3:15–3:30	10	143.28	30	147.01	+3
3:30–3:45	11	146.42	31	148.87	+2
3:45–4:00	12	150.95	32	153.64	+2
4:00–4:15	13	153.82	33	155.41	+1
4:15–4:30	14	176.40	34	169.10	-4
4:30–4:45	15	180.06	35	174.92	-3
4:45–5:00	16	192.21	36	179.62	-7
5:00–5:15	17	220.26	37	199.18	-11
5:15–5:30	18	204.66	38	190.33	-8
5:30–5:45	19	187.51	39	184.87	-1
5:45–6:00	20	171.34	40	169.64	-1

Note: PI = performance index.

The PIs in Table 7 were plotted versus time of day in Figure 4. The solid curve represents the off-peak cycle length, and the dashed curve represents the peak cycle length. The two plots show that for both cycle lengths, the PI increased as the afternoon progressed and volumes increased. Compared with the 115-sec cycle length, the 85-sec cycle length produced lower PIs during the off-peak period and higher PIs during the peak period. The 115-sec cycle length produced higher PIs during the off-peak period and lower PIs during the peak period. The optimal time to change the timing plan from off-peak period to peak period was determined to be 4:15 p.m., where the two curves cross.

SOAP/M Output Results

The SOAP/M program was applied to the critical intersection, Piedmont and Marian roads (Node 5). It

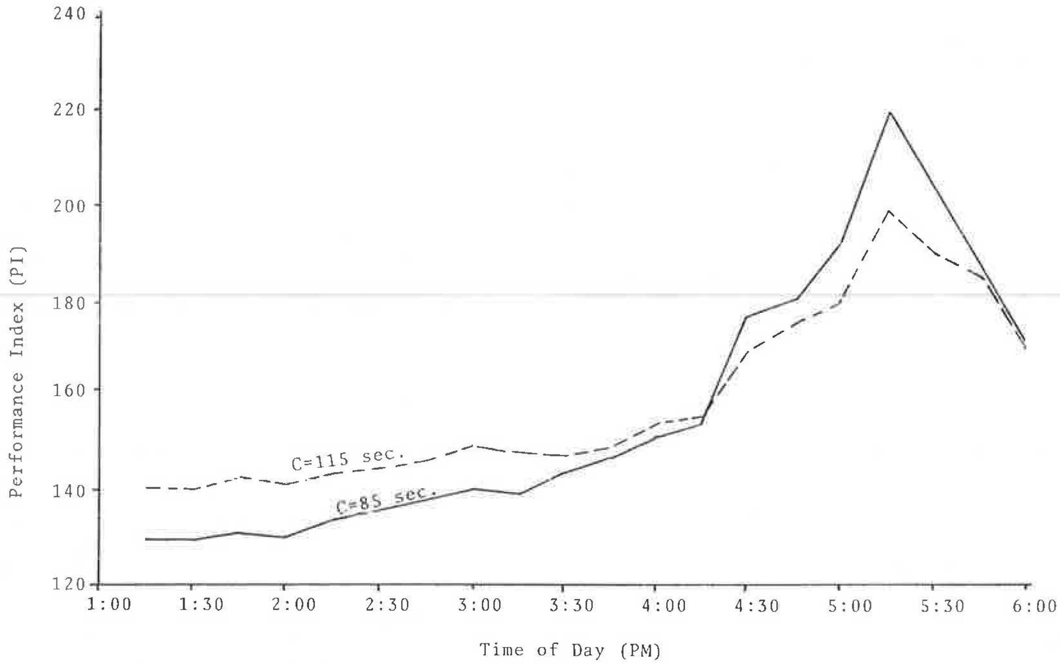

FIGURE 4 Optimal time of changing timing plans from off-peak to peak period.

was hoped that this simpler analysis might produce an optimal time to change timing plans similar to the time indicated by the TRANSYT-7F procedure.

The SOAP/M program was used to evaluate the off-peak cycle length and peak-hour cycle length that were selected by the TRANSYT-7F program for the coordinated arterial system. The TRANSYT-7F input data of Node 5 for every 30-min interval were provided for the SOAP/M program. Ten runs were made for the 85-sec off-peak cycle length at 30-min intervals from 1:00 to 6:00 p.m. (Table 8). Another 10 runs were made for the 115-sec peak cycle length at the same time intervals (Table 9).

It is indicated in Tables 8 and 9 that the off-peak cycle length performed better in terms of total delay, but that the peak cycle length performed better in terms of the percentage of stops. Fuel consumption for any one time of day was essentially the same for both cycle lengths. The off-peak cycle length had a better PI than the peak cycle length at all times; therefore, the SOAP/M analysis failed to produce an optimal time to change the timing plan.

Figure 5 shows a plot of the PIs versus the period of time from 1:00 to 6:00 p.m. The solid-line plot represents the off-peak cycle length and the dashed-line plot represents the peak cycle length.

TABLE 8 SOAP/M Results for Node 5 for Off-Peak Cycle

Time Period (p.m.)	Run No.	Total Stop (%)	Total Delay (veh-hr/hr)	Fuel Consumption (gal/hr)	Performance Index
1:00–1:30	1	69	17	36	34.87
1:30–2:00	3	70	17	37	35.21
2:00–2:30	5	69	17	37	35.22
2:30–3:00	7	71	18	39	37.08
3:00–3:30	9	72	19	40	38.67
3:30–4:00	11	72	19	41	39.02
4:00–4:30	13	76	23	47	46.20
4:30–5:00	15	77	24	50	48.76
5:00–5:30	17	78	24	53	50.46
5:30–6:00	19	76	23	49	47.15

Note: C = 85 sec.

TABLE 9 SOAP/M Results for Node 5 for Peak Cycle

Time Period (p.m.)	Run No.	Total Stop (%)	Total Delay (veh-hr/hr)	Fuel Consumption (gal/hr)	Performance Index
1:00–1:30	2	63	22	37	38.32
1:30–2:00	4	63	22	37	38.39
2:00–2:30	6	63	21	37	37.63
2:30–3:00	8	64	22	38	39.20
3:00–3:30	10	66	24	40	42.03
3:30–4:00	12	66	24	41	42.35
4:00–4:30	14	71	29	49	50.67
4:30–5:00	16	72	30	52	53.16
5:00–5:30	18	71	30	53	54.18
5:30–6:00	20	71	29	51	51.56

Note: C = 115 sec.

The figure shows that the off-peak cycle length performed better than the peak cycle length at all times.

SUMMARY AND CONCLUSIONS

Optimal off-peak and peak-hour timing plans for the afternoon hours for this particular arterial were produced in this study. A technique was demonstrated for determining the optimal time to change the off-peak timing plan to the peak-period plan. The PASSER results appear to have been improved by allowing TRANSYT to perform its optimization procedure on them. A SOAP/M analysis of the critical intersection failed to indicate an optimal time to change plans; there was no indication that SOAP/M could replace the more involved TRANSYT analysis of the entire route.

ACKNOWLEDGMENT

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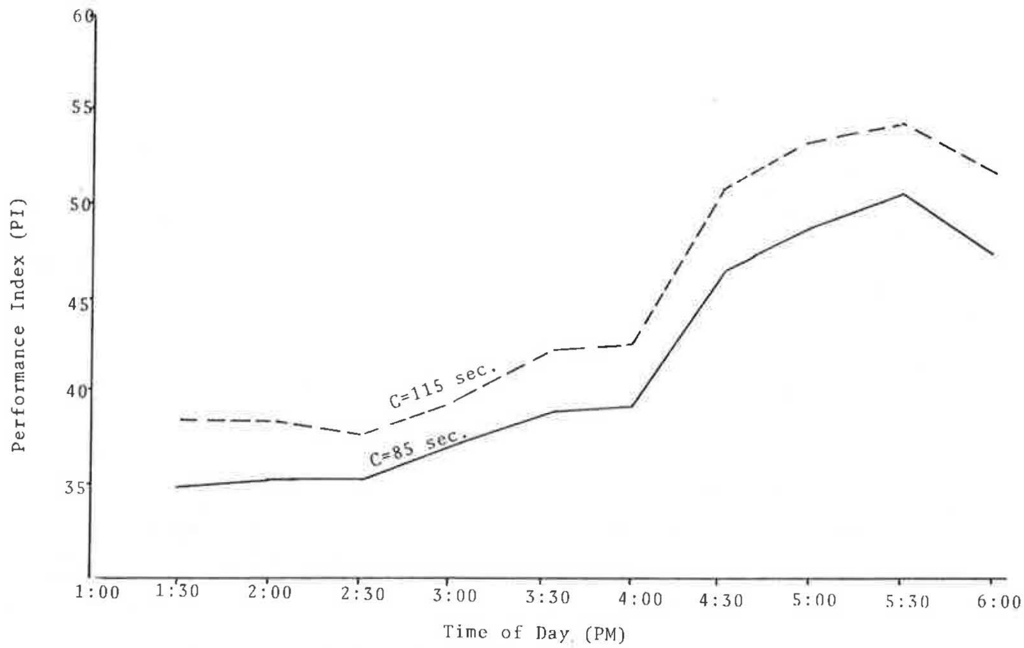

FIGURE 5 SOAP/M runs on Node 5 as an isolated intersection.

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Discussion

Edmond Chin-Ping Chang*

In the paper by Jrew and Parsonson, the uses of three off-line computer programs to determine the optimal time to change the arterial signal-timing plans for a particular Atlanta arterial were studied. Attempts were made to develop guidelines to select the optimal signal-timing plans between the off-peak and peak-hour periods by using the PASSER II-80, TRANSYT-7F, and SOAP/M computer programs.

Mainly, two experiments were performed to evaluate the alternatives of

1. Using either PASSER II-80 or TRANSYT-7F to indicate the optimal time to change the arterial traffic signal-timing plan; and
2. Avoiding the time-consuming TRANSYT-7F computerized procedure by evaluating only the critical intersection with the SOAP/M analysis.

The optimal timing plans were developed for both the off-peak and peak-hour traffic using PASSER II and TRANSYT-7F. It was expected that two different cycle lengths might be obtained for the off-peak and peak-hour traffic. The optimal timing plan was then run forward in time, with the volumes increasing from the off-peak to peak hour. A plot was prepared for performance index (PI) versus time of day. The optimal peak-hour plan was then simulated backward in time by using the traffic volumes tracking back from peak-hour to off-peak period; a second performance curve was obtained. The intersection of the two curves could indicate the optimal time to change timing plan.

However, the study results did not completely meet the expectation that an indication of the optimal time to change the arterial signal-timing plans for this particular arterial would be provided. First, the PASSER II-80 run did not indicate two separate optimal cycle lengths for the off-peak hour and peak hour. Therefore, the same process was repeated using TRANSYT-7F. The TRANSYT analysis results indicated that the shorter cycle did not perform significantly worse than did the longer cycle during the off-peak period. It also indicated that the longer cycle length performed better than the shorter cycle length during the peak hour. The optimal time to recommend signal-timing changes was determined. Finally, the SOAP/M program was run forward and backward in time by using the same volume level for the critical intersection. It was hoped that this simplified approach would indicate approximately the same time of day for changing timing plans as was indicated by TRANSYT-7F. However, the SOAP/M analysis resulted in only one plan for the entire off-peak and peak period, as was obtained using PASSER II-80. It was therefore concluded in the Jrew and Parsonson paper that the critical intersection approach could not successfully indicate an optimal time to change the timing plan and the approach should not be used for this purpose.

Several points should be noted from this investigation:

1. It is very difficult to provide an optimal solution if only a two-phase signal phase control option is used in the PASSER II analysis.

*Texas Transportation Institute, Texas A&M University System, College Station, Tex. 77843-3135.

2. Good initial solution is important for TRANSYT-7F because of the possibility of reaching a local optimization solution in a TRANSYT-7F analysis (1).

3. PASSER II does provide variations in measurements of effectiveness (MOEs) evaluated on the approach, intersection, and arterial system level.

4. Most existing arterial signal-timing optimization methods were developed for fixed-time traffic signal equipment. This requires that coordinated timing plans for an actuated signal system be converted to its equivalent pretimed settings, which sometimes means loss of some advantages of actuated signal control (2).

5. The latest evolution of the PASSER II-84 model provides additional advantages by offering the performance evaluations closely related to the 1985 Highway Capacity Manual (3).

One major advantage of PASSER II is its ability to provide the best combination of cycle and phase sequences for maximizing the total two-way progression. In this study, it was decided not to optimize the phasing other than to use the existing two-phase operation. Because PASSER II was not allowed to optimize the phasing, the cycle was basically controlled by the critical lane volume of the conflicting movement pairs at the critical intersection. It was also noted that the levels of traffic volume remained the same regardless of time of day, as indicated in the SOAP/M analysis. Therefore, it is obvious that neither PASSER II-80 nor SOAP/M would show any differences between the optimized cycle lengths in the evaluation.

There are increasing concerns that the data preparation and analysis efforts required for using TRANSYT-7F be reduced. It is also desired that a minimum-delay arterial timing plan that has good progressive operation be provided. A proven successful approach is to use MAXBAND or PASSER II to generate the maximum bandwidth solutions as starting initial solutions for the subsequent TRANSYT-7F analysis. It can also guarantee the initial green times, offsets, and progression bandwidth to provide a base point for arterial signal-timing optimization. The detailed data collection procedures documented in the TRANSYT-7F manual provide excellent guidelines for the general users.

PASSER II MOEs can provide good and consistent evaluations of the optimal arterial signal-timing plans for design analysis and operation evaluation on the arterial progression operations. To demonstrate the variability in PASSER II performance evaluations, a series of PASSER II-84 runs were made using the Skillman Avenue example. The PASSER II-84 performance evaluations of this particular data set are shown in Figure 6, which shows arterial systemwide measurements versus background cycle length. The progression efficiency and average system delay are plotted against cycle length ranging from 65 sec to 130 sec, as shown separately on the curves in Figure 6. As indicated, the arterywide measurements depend on the different cycle lengths selected by PASSER II under quad-left, multiple-phase operations for this particular coordinated arterial.

Level-of-service criteria were updated in the PASSER II-84 version 2.3B package to conform to the new technology developed in the 1985 Highway Capacity Manual. PASSER II-84 provides several operational MOEs separately for each traffic movement, intersection, and arterial system. These measures can be used to evaluate the existing operations or estimate the proposed signal-timing plan. Generally, the accepted performance evaluation criteria for describing level of service for individual movements used in PASSER II-84 are as shown in Table 10.

TABLE 10 Accepted Performance Evaluation Criteria for Describing Level of Service for Individual Movements Used in PASSER II-84

Level of Service	Volume-to-Signal Capacity Ratio	Movement Delay (sec/veh)	Probability of Clearing Queue
A	≤0.60	≤ 6.5	≥0.995
B	≤0.70	≤19.5	≥0.90
C	≤0.80	≤32.5	≥0.75
D	≤0.85	≤52.0	≥0.50
E	≤1.00	≤78.0	<0.50
F	>1.00	>78.0	<0.50

The delay criteria used in PASSER II-84 are equivalent to the average delay criteria established by the Highway Capacity and Level of Service Committee of the Transportation Research Board in the 1985 Highway Capacity Manual for stop delay of (5, 15, 25, 40, 60) where average delay equals 1.30 times the stop delay. The ratios used in PASSER II-84 for evaluating volume-to-signal capacity ratio

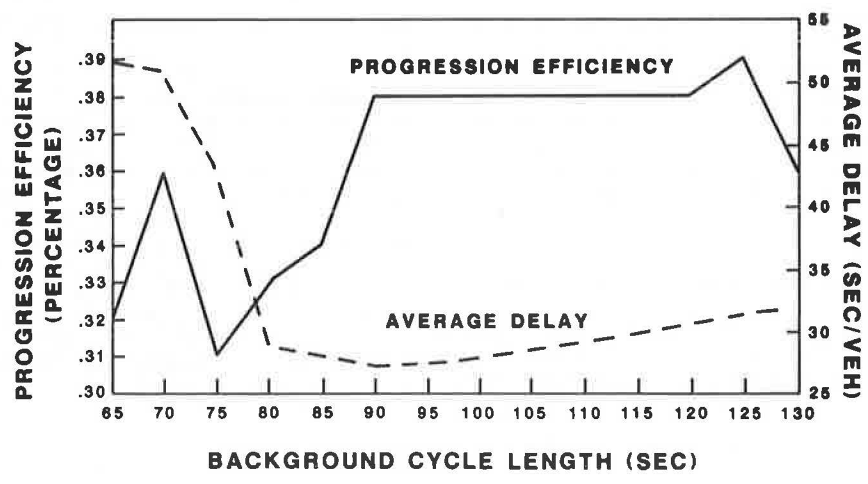

FIGURE 6 PASSER II-84 performance evaluations: arterial systemwide measurements versus background cycle length.

(v/c, saturation or the x ratio) are reasonable criteria. There are no generally accepted criteria for v/c ratio or probability of queue clearance for intersections. It should be noted, however, that traffic delays usually become excessive at volume-to-capacity ratios exceeding 0.85.

Long cycle lengths tend to increase arterial progression efficiency and reduce the volume-to-signal capacity ratio, but at the same time increase arterial system delay. Excessively long cycles may create lane blockage and driver confusion on the cross street, and account for reductions in saturation flow rate. Research in Canada also suggests that green-light durations of longer than 50 sec may also become inefficient for traffic operation. Therefore, it is common practice in PASSER II analysis to provide the widest range in the first run to optimize the green splits, cycle length, and phase sequences for the entire arterial. Then, a desirable cycle range of plus and minus 5-sec range according to the MAXMIN DELAY CYCLE LENGTH of the most critical intersection is coded for the maximum and the minimum allowable cycle length ranges. Several arterial optimization runs could then be made to provide better evaluation of the alternative timing plan by specifying different geometric design options, traffic volume, traffic flow characteristics, and signal-timing control parameters.

On the other hand, the modeling of actuated arterial signal operations requires detailed time-series analysis to analyze the effects of variations in traffic volumes. A need exists for developing macroscopic arterial traffic signal models to study and optimize timing plans for arterial signal systems with actuated signal controllers. Approaches similar to that used in the FREQ-model can provide a tool for evaluating different arterial traffic congestion management strategies with respect to different times of day.

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Authors' Closure

The authors thank the discussant for taking the time to prepare a discussion of their paper.

The first four paragraphs of his discussion are essentially a summary of the paper. A sentence in his fourth paragraph states "Finally, the SOAP/M program was run forward and backward in time by using the same volume level for the critical intersection." Our paper states that "the volumes used were for each 30-min time of day," so the discussant probably intends that his sentence state ". . . using the same volume levels. . ."

The fifth paragraph of the discussion begins "Several points should be noted from this investigation." The discussant's point is that "It is very difficult to provide an optimal solution if only a two-phase signal phase control option is used in the PASSER II analysis." Later, in the sixth paragraph, he states that "In this study, it was decided not to optimize the phasing other than to use the existing two-phase operation." There appears to be a misunderstanding here. Nowhere in the paper is it stated that the signals had only two phases, nor did we say that during our oral presentation at the Transportation Research Board's 65th Annual Meeting. Actually, several signals had more than two phases.

The discussant's second point is that TRANSYT-7F needs to begin with a good initial solution. Possibly, he suspects that our TRANSYT results were local, not global, optima because of poor initial settings. It is stated in our paper that "The output timing data of PASSER II were used as input timing for all the TRANSYT-7F runs." Further, the step sizes of the TRANSYT optimization iterations were selected by using the standard pattern known to be successful in breaking out of a local optimum.

The discussant's third point is that PASSER II provides a number of MOEs. The authors agree, but are not sure what his point is with respect to this paper.

The discussant goes on to mention (in the fourth item on his list of points to note from the investigation) that timing plans (developed for fixed-time controllers) sometimes are implemented by using actuated controllers. This is true, but the authors do not understand how this is a comment on our paper; we did not mention the type of controllers on our arterial nor did we present any data that was linked to the controller type.

The discussant's fifth point is that the latest version of PASSER, called PASSER II-84, provides certain advantages. Perhaps he is hinting that our results would have been different in some way had this version been available at the time of our research.

In the next paragraph, the discussant states that in our research "the levels of traffic volume remained the same regardless of time of day, as indicated in the SOAP/M analysis." The authors interpret this to mean that he believes that our SOAP/M analysis used constant volumes, the same for all times of day. We do not understand this comment because it is stated in our paper that the volumes used were for each 30-min time of day.

In his next paragraph, the discussant recommends that MAXBAND or PASSER II be used to generate initial settings for subsequent TRANSYT-7F analysis. The authors agree; it is stated in our paper that we used PASSER.

The remainder of the discussant's comments deal primarily with PASSER II-84's level-of-service criteria and with selection of cycle length. Neither of these points appears to be directed at our paper.