Evaluating the effectiveness of signal timing optimization based on microscopic simulation

Evaluación de la efectividad de la programacion óptima de semáforos basada en simulación microscópica

Patricio Álvarez[1] and Mohammed A. Hadi[2]

[1] Departamento de Ingeniería Civil y Ambiental, Universidad del Bío-Bío, Av. Collao 1202, Casilla 5-C, Concepción, Chile, palvarez@ubiobio.cl
[2] Lehman Center for Transportation Research, Department of Civil and Environmental Engineering, College of Engineering and Computing, Florida International University, 10555 W. Flagler Street, EC 3605, Miami, USA, hadim@fiu.edu

Previous studies have shown that there are inconsistencies between the assessments of signal timing plans based on the results of optimization tools that use macroscopic simulation models and the assessments of the same plans based on microscopic simulation models. The studies show that the signal timing plans, identified to be optimal by the optimization tools, are determined to be not optimal and sometimes do not perform well according to microscopic simulation assessments. However, no attempts have been made in previous studies to determine the reasons behind these inconsistencies. This paper investigates whether adjusting the parameters of the macroscopic simulation models to correspond to the calibrated microscopic simulation model parameters can reduce the above mentioned inconsistencies. The results show that adjusting the values of platoon dispersion parameters, coded cruise speeds, and saturation flow rates in the macroscopic simulation models can have significant impacts on the performance of the signal timing plans as assessed by microscopic simulation.

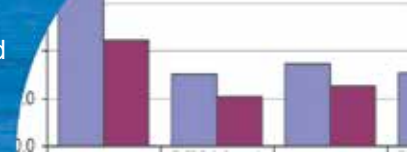*Keywords: simulation models, optimization models, traffic models, traffic signals*

Estudios previos han señalado que existen inconsistencias en los programas de optimización a implementar en redes controladas por semáforos dependiendo si dichos programas han sido obtenidos por medio del uso de modelos de simulación macroscópicos o microcópicos. En esos estudios además se indica que las programas de operación que típicamente se identifican como óptimos usando modelos de optimización macroscópicos, no necesariamente presentan un comportamiento óptimo cuando se implementan y prueban en modelos microscópicos de simulación de tráfico. Pese a esto, no existen registros en la literatura que investiguen las razones detrás de dichas inconsistencias. En este trabajo se investiga si al ajustar los parámetros del modelo de simulación macroscópico, de tal forma de representar de mejor forma los parámetros del modelo microscópico, se pueden reducir las inconsistencias entre ambos enfoques de modelación. Los resultados indican que ajustar los parámetros del modelo de dispersión de pelotones, las velocidades medias de operación y los flujos de saturación en el modelo de simulación macroscópico, tiene impactos significativos en la optimalidad de los planes propuestos al ser implementados y probados en modelos de simulación microscópicos.

Palabras claves: modelos de simulación, modelos de optimización, modelos de tránsito, señales de tránsito

Introduction

Signal timing optimization programs have been developed to identify the optimal timing plans to minimize delays, stops, and fuel consumptions and/or to maximize progression opportunities between signals. The family of models TRANSYT-7F Traffic Network Study Tool Version 7 (Hale, 2006), PASSER Progression Analysis and Signal System Evaluation Routine (Chaudry *et al*., 1988),

and SYNCHRO (Hush and Albeck, 2006) are examples of existing commercially available signal timing optimization programs.

Signal timing optimization programs have used macroscopic simulation models and/or analytical mathematical relationships to assess the values of the objective functions during the optimization process. Previous studies have attempted to evaluate the effectiveness of the resulting timing plans using microscopic simulation tools like CORSIM Corridor Simulator (FHWA, 1997). These studies show that signal timing plans, identified to be optimal by the optimization tools, are determined to be not optimal and sometimes do not perform well according to microscopic simulation model assessments. Park *et al.* (2001) investigated the extent to which TRANSYT-7F optimized signal timing plans for a nine intersection arterial street appeared to be close to the optimal plans when evaluated in CORSIM. CORSIM was calibrated based on the observed maximum queue lengths at key intersections in the field. The optimal plans in TRANSYT-7F were obtained based on measures of performance that are directly comparable with those provided by CORSIM, namely delay, fuel consumption, percent stops, queue time and throughput. Twelve optimization strategies (objective functions) in TRANSYT-7F were tested to produce the optimized plans. Considerable differences were observed between TRANSYT-7F and CORSIM assessments of the performance of the optimal plans.

Ruphail *et al.* (2006) used CORSIM simulation results to evaluate the performance of timing plans optimized using TRANSYT-7F for a nine intersection arterial system compared to the plans obtained using a Genetic Algorithm GA in combination with CORSIM simulation of the alternative solutions during the optimization. The study found that the CORSIM-based GA optimization consistently outperformed TRANSYT-7F optimization.

Stevanovic and Martin (2006) examined the performance of aging signal timing plans for an uncongested hypothetical network. TRANSYT-7F and SYNCHRO were used in the optimization and three different simulation tools were used in the microscopic simulation. The study also investigated the performance of timing plans obtained using direct optimization in microscopic simulation using the CORSIM-based GA optimization approach. All programs

were utilized with the default settings of their parameters. The results indicated systematically inconsistent outcomes for most of the optimization and microscopic simulation program combinations. Additionally, the direct optimization using GA in CORSIM did not generate significantly better timing plans than those obtained using TRANSYT-7F and SYNCHRO.

Previous studies have not attempted to determine the reasons behind the inconsistencies between optimization and microscopic simulation tool results. One of the main reasons for the inconsistencies is expected to be the differences in the arrival and departure traffic patterns at the signalized intersections as assessed by the microscopic and macroscopic simulation models. These differences could be related to the values used for the macroscopic and microscopic model parameters such as lost time, saturation flow rate/time headway, speed, gap acceptance parameters, and platoon dispersion parameters. This study investigates whether adjusting the macroscopic simulation model parameters in a signal timing optimization tool can achieve a better correspondence of the values of the performance measures obtained from the optimization tool with those assessed by microscopic simulation. The tools used for the purpose of this study are the TRANSYT-7F signal timing optimization software and the CORSIM microscopic simulation software. These are two of the most widely used signal timing optimization and simulation tools.

TRANSYT-7F model parameters

Traditionally, TRANSYT-7F optimization has been based on minimizing delays, number of stops, or a combination of the two. The delays and number of stops are assessed using a macroscopic simulation model. Hadi and Wallace (1992) extended TRANSYT-7F capabilities to optionally optimize the signal timing based on the progression opportunities between intersections. Later, Hadi *et al.* (1999) modified the simulation and optimization models of TRANSYT-7F to optionally optimize the signal timing parameters for congested conditions based on throughputs, queue lengths, or combinations of these two parameters.

The TRANSYT-7F macroscopic simulation model assesses the arrival patterns at the downstream signals based on the volumes released from upstream intersections at each time step, the link travel time, and a platoon dispersion model.
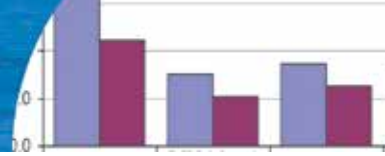
The model determines the departure patterns based on the arrival rates, saturation flow rates, and the green time at each time step during the signal cycle. TRANSYT-7F then uses the arrival and departure patterns as the bases for calculating various measures of effectiveness.

TRANSYT-7F uses a platoon dispersion algorithm developed by Robertson (1969) to model the dispersion of traffic along the link. The Robertson's model takes the following mathematical form:

$$q'_t = Fq_{t-T} + (1-F)q'_{t-\Delta t} \tag{1}$$

$$F = \frac{1}{1+\alpha\beta T_a} \tag{2}$$

$$T = \beta T_a \tag{3}$$

where q'_{t-T} is the flow rate over a time step Δt arriving at the downstream signal at time t (vehicles per time step unit), q_{t-T} is the discharging flow over a time step Δt observed at the upstream signal at time $t-T$ (vehicles per time step unit), $q'_{t-\Delta t}$ is the flow rate over a time step Δt arriving at the downstream signal at time $t-\Delta t$ (vehicles per time step unit), Δt is the modeling time step duration (units of time steps), F is the smoothing factor (units of time steps^{-1}), α is the platoon dispersion factor to adjust the model according the amount of side friction along the link (unitless), β is the travel time factor (unitless) and T_a is the mean roadway travel time (units of time steps).

The TRANSYT-7F software defaults for the platoon dispersion parameters α and β are 0.35 and 0.8, respectively. The TRANSYT-7F manual mention that the default α value is for links with moderate friction to the traffic stream and recommends the use of α value of 0.5 for heavy friction and 0.25 for low friction. TRANSYT-7F allows the user to vary the value of α but the β value is kept fixed at 0.8. The higher the value of the platoon dispersion factor α, the more is the platoon dispersion. A value of 0.0 for α represents no platoon dispersion while a value of 1.0 results in the maximum dispersion. The lower the value of β, the earlier traffic arrives at the downstream intersection as estimated by the platoon dispersion algorithm. It can be hypothesized that varying the values of the platoon dispersion model parameters to allow better correspondence between the arrival patterns in

TRANSYT-7F and those in CORSIM, will result in closer estimates of the performance measure values between the two tools.

In addition to platoon dispersion model parameters, the arrival pattern in TRANSYT-7F is affected by the coded link speed. This input should be set to the estimated cruise speed. TRANSYT-7F does not have an internal model to adjust the coded speed to estimate the cruise speed according to the actual level of traffic in the system. However, in most cases, the program users have input the speed limits or free flow speeds instead of the cruise speeds because of the difficulty in estimating the cruise speed, in the absence of travel speed measurements in the field.

Stop line departure patterns in TRANSYT-7F are affected by the coded saturation flow rates and the coded lost times of the traffic movements. For permitted movements and shared-lane movements, they are also affected by the parameters of the permitted movement and shared-lane models, respectively. In general, the TRANSYT-7F User's Manual recommends field measurement of saturation flow rates. However, in practice, most users of the program have used the saturation flow estimation procedures presented in the Highway Capacity Manual HCM 2000 TRB (2000) or simplified versions of these procedures to estimate the saturation flow rates.

In CORSIM, the cruise speed, saturation flow/departure rate, and platoon dispersion are products of the microscopic simulation models such as car following, lane changing, queue discharge, driver reactions to yellow and green, and gap acceptance. The results from these models depend on a large number of microscopic model parameters that are usually modified by the users in the simulation model calibration process to achieve values of performance measure outputs that are close to those observed in the field.

Methodology
Overview
The above discussion indicates that there are several parameters that can be calibrated in both macroscopic and microscopic models to affect the results of these models. This section describes the method used to determine if calibrating macroscopic model parameters can result in better correspondence between the macroscopic and

microscopic model (TRANSYT-7F and CORSIM) results. This investigation was based on four case studies, as described later in this section.

Initially, the signal timing plans were optimized for the case studies using initial values for the platoon dispersion, cruise speed, and saturation flow rate input parameters in TRANSYT without considering CORSIM assessments of these parameters. The performances of the resulting optimized signal timing plans were then assessed using CORSIM. Next, the values of the above mentioned input parameters in TRANSYT-7F were adjusted to reflect CORSIM assessments of these parameters, as described later in this section. CORSIM was then used to determine if the adjustments in the parameter values can improve the performances of the optimized signal timing plans.

Case study description

The methodology used in this study was applied to four systems that differ in complexity from a simple hypothetical two-node system to a real-world arterial corridor. Below is a description of these systems.

Systems A: This is a simple two node system with no turning left or right movements from the two cross streets. This system was used for an initial exploration of the effects of calibration parameters. The investigation varied the link length that connects the two intersections and the value of the volume to capacity (V/C) ratio at the downstream signalized intersection. Conditions with V/C ratios above 1.0 were not investigated because they include the effects of queue spillback, which need to be investigated in a separate study.

System B: The only difference between this system and System A is the addition of left and right turning feeding movements from the cross street at the upstream intersection, in addition to the through feeding link, to represent a somewhat more realistic condition. The investigated link length was 610 m and the V/C ratio at downstream intersection was 1.0.

System C: This system represents a real world arterial corridor. This is the US -1 corridor between SW 136th Street and SW 98th Street in Miami, Florida. The system is an arterial system that is 5.4 km long and includes seven coordinated signalized intersections. The traffic demands

used in the investigation were the PM peak period demands for this network. However, the volumes on some of the movements were reduced to ensure that the V/C ratios for all movements were below 1.0 in the investigation.

System D: This system is a variation of the US-1 corridor mentioned above. In addition to reducing the demand as was done for System C, the lengths of the longer links were also reduced to determine the effects of this reduction on the results.

Cruise speed values

Initially, the free flow speed was input to both TRANSYT-7F and CORSIM, as is usually done by the users of the two tools. CORSIM internally adjusts the speed of the vehicles to reflect the attributes of the traffic stream. TRANSYT-7F does not have this capability. Thus, the macroscopic simulation of TRANSYT-7F uses the speed coded by the user in its assessments.

To determine the values of the cruise speed as assessed by CORSIM for a given arterial link in this study, the signal control was removed from the downstream end of the link and the speed on the link was computed based on the time and position trajectory data of each vehicle. This data was collected from the CORSIM binary TSD file using a Visual Basic script developed by John D. Leonard II of Georgia Institute of Technology.

Table 1 shows that, as expected, the cruise speed in CORSIM is lower than the coded speed due to the simulated interaction between vehicles. For example, the cruise speed in system A (the simple two intersection system) ranged between 87% of the coded free-flow speed for a V/C ratio of 0.8 to 79% of the coded speed for a V/C ratio of 1.0. For Systems C and D, the average cruise speed on the system links were about 80% of the average of the coded speeds.

In this study, TRANSYT-7F results were compared with CORSIM results with three coded link speeds in TRANSYT-7F: speed limit, cruise speed as assessed by CORSIM, and cruise speed as assessed by CORSIM but multiplied by a reduction factor of 0.8. The rationale behind using this reduction factor is to eliminate the early arrival of vehicles in TRANSYT-7F macroscopic simulation, as explained later in this paper.
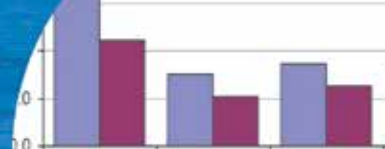
Table 1: Cruise speed of different systems as assessed by CORSIM

Attribute	Systems A						Systems C and D
Link length, m	76			610			Varies according to US-1 segments
V/C ratio	0.8	0.9	1.0	0.8	0.9	1.0	
Coded speed, km/h	56						64
CORSIM-assessed speed, km/h	49.1	48.5	44.6	48.5	48.5	44.6	57.6

Saturation flow rate

The capacity of a protected movement at a signalized intersection is a function of the saturation flow rate, lost time, and effective green time of the movement. The saturation flow rate in vehicles per hour of green is an input to TRANSYT-7F. In this study, the unadjusted (initial) values of the saturation flow rates coded in TRANSYT-7F were obtained using the HCM estimation procedure.

The average queue discharge headway rate in seconds per vehicle, which is the inverse of saturation flow rate, is a required input for each signalized intersection approach in CORSIM. This parameter is normally used by the user to calibrate the capacity of individual movements to reflect field conditions. CORSIM, being a stochastic model, generates the actual time headways during the simulation based on the coded average headway for a movement from

a headway distribution that considers the variations in driver characteristics. Since CORSIM does not output the actual value of the average saturation flow rate resulting from the simulation, it was necessary in this study to estimate these values based on the throughput when the demand exceeds capacity.

Table 2 shows the saturation flow rates initially coded in TRANSYT-7F, the queue discharge headways measured in CORSIM, and the estimated saturation flow rates based on CORSIM outputs. First, the signalized timing plans were optimized in TRANSYT-7F using the initial values of saturation flow rates obtained based on the HCM procedure. Then, the optimization was repeated with the values of saturation flow rates updated to reflect the values of the saturation flow rates measured in CORSIM. CORSIM was then used to assess the resulting timing plans from the two sets of optimization.

Platoon dispersion parameters

The unadjusted platoon dispersion parameters used in this study were the defaults used in the program (β equal to 0.8 and α equal to 0.35). In the runs with the adjusted parameters, only α could be changed since the β value is fixed and built in the program. However, the β value can be adjusted indirectly by changing the coded cruise speed since β is basically a multiplier of travel time in the platoon dispersion model, as indicated by equations (1) to (3).

Platoon dispersion characteristics are not output by CORSIM. Thus it was necessary to obtain this information based on the arrival patterns stored in a binary output file from CORSIM (the TSD file). The Visual Basic script mentioned earlier was used to access the TSD file. The

Table 2: Saturation flows initially coded in TRANSYT-7F and those assessed by CORSIM

After adjustment	System A	System B			Systems C and D			
	Thru	Thru	Dual right turn	Dual left turn	Thru	Single left turn	Single right turn	Dual left turn
Time headway (s/veh) measured from CORSIM	1.72	1.72	2.10	2.0	2.00	2.00	2.33	1.99
Saturation flow rate veh/hr/ln measured from CORSIM	2088	2088	1700	1800	1800	1800	1548	1809
Saturation flow rate veh/hr/ln initially coded in TRANSYT-7F	1800	1800	1710	1620	1800	1620	1710	1620

Note: the average time headway coded in CORSIM for intersection approaches is 1.8 s/veh
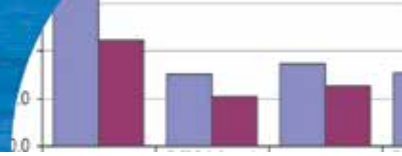
arrival profile can be determined by counting the number of vehicles passing by a control section in a given time interval based on TSD data.

Seddom (1972) presented further expansion of the recurrence dispersion equation provided in (1) to (3) above. This expansion resulted in the following form of the model:

$$q_t' = \sum_{i=T}^{\infty} \left[F(1-F)^{i-T} \right] q_{t-i} \qquad (4)$$

Equation (4) illustrates that the link travel time in the TRANSYT-7F platoon dispersion model actually follows a shifted geometrics distribution (shifted T seconds to the right from the origin). Applying the basic properties of a geometric distribution to the previous equation will result in the following equation to express the smoothing factor F based on the standard deviation of the link travel times σ:

$$F = \frac{\sqrt{1+4\sigma^2} - 1}{2\sigma^2} \qquad (5)$$

By setting β to its fixed value in TRANSYT-7F (0.8), α can be calculated by combining (4) and (5) based on σ and T. Yu (2000) used this approach to calculate the α value based on field data. He estimated the value of α to be 0.09 for a link with a length of 320 m and 0.14 for a link with a length of 560 m, as indicated in Table 3.

In the current study, travel time data output by CORSIM to the TSD file were extracted using the extraction Visual Basic script. The average and standard deviation of travel time were calculated based on this data allowing the estimation of α and F using (4) and (5). Table 3 shows the results from Yu (2000) based on field data and the results obtained in this study based on CORSIM data. Table 3 indicates that the values of α from both studies are comparable and considerably lower than the default value used as default in TRANSYT-7F (0.35) and the range of values recommended by TRANSYT-7F (0.25 to 0.50). Based on the results of Table 3, the values of F and α appear to be higher for lower link lengths and lower V/C ratios. Since the obtained α values based on CORSIM travel time data are close to 0.1 (see Table 3), this study used this value (0.1), the adjusted α value in the TRANSYT-7F runs with the adjusted parameters.

TRANSYT-7F optimization

As mentioned earlier, initially signal timing optimization was conducted utilizing TRANSYT-7F with the default values of the macroscopic simulation model parameters. Then, the optimization was repeated with TRANSYT-7F parameters adjusted to reflect speeds, saturation flow rates, and platoon dispersion parameter values estimated based on CORSIM runs. All optimizations in TRANSYT-7F were performed using the minimization of delay criteria and utilizing the default "Hill-climbing" optimization algorithm. The measure of performance used to assess the quality of the resulting timing plans in CORSIM was the control delay time.

CORSIM simulation runs

Each evaluated scenario was simulated ten times with different seed numbers. A statistical test was conducted to determine if ten runs are sufficient for a number of link length and V/C ratio combinations simulated in CORSIM.

Table 3: Estimation of the value of the platoon dispersion factor

Study	Traffic conditions	Link length, m	Average travel time, s	Travel time standard deviation	F	α
Yu (1996) based on field data	Heavy traffic	320	23.66	2.22	0.36	0.09
	Heavy traffic	560	40.50	4.85	0.19	0.14
This study based on CORSIM data	V/C=0.9	76	6.14	0.89	0.66	0.11
	V/C=1.0	76	6.26	0.71	0.73	0.07
	V/C=1.0	153	12.41	1.44	0.49	0.10
	V/C=1.0	305	24.42	1.88	0.41	0.07
	V/C=0.8	610	48.47	4.29	0.21	0.10
	V/C=1.0	610	49.80	3.92	0.22	0.09

The test was performed using the following formula:

$$d = t_{n-1,1-\alpha/2} \frac{S}{\sqrt{N}} \qquad (6)$$

where N is the number of runs, S is the standard deviation in cruise speed for the runs with different seed number, d is the error in cruise speed measurements in km/h, and $t_{n-1,1-\alpha/2} = 2.262$ that correspond to 95% level of confidence in t-Student probability distribution function.

It was found that 10 runs produced errors in the cruise speed of 3% or less for all tested scenarios. This was considered acceptable for the purpose of this study. Thus, 10 runs with the same set of different seed numbers were performed for each scenario to eliminate variations due the use of different set of seed numbers for different scenarios.

Results
Comparison of TRANSYT-7F and CORSIM platoons
Figure 1 shows a comparison between the arrival patterns resulting from TRANSYT-7F runs, with different values of α, downstream of a 610 m link. The link has one upstream thru feeder link. The V/C ratio at the downstream intersection according to TRANSYT-7F evaluation is 1.0. Figure 1 shows that lower values of α produced less platoon dispersion in TRANSYT-7F, with α equal to zero resulting in no platoon dispersion. Figure 1 also shows the arrival pattern predicted by CORSIM for the same link. In terms of shape, it appears from Figure 1 that the arrival pattern produced by TRANSYT-7F with α = 0.1 is the closest to that of CORSIM but it is shifted to the left compared to the CORSIM pattern. This indicates that vehicles are arriving earlier in TRANSYT-7F compared to CORSIM due to the internal assessment by CORSIM of the impact of the interactions between vehicles on the average cruise speed and possibly also due to the default value used for β in the platoon dispersion model of TRANSYT-7F (β is the travel time multiplier which has a default value of 0.8, as described earlier).

Figure 2 presents a comparison between the arrival pattern predicted by CORSIM and the patterns predicted by TRANSYT-7F with the values of α fixed at 0.1 but for different speed values. The investigated speed values in TRANSYT-7F included the unadjusted initial speed coded in TRANSYT-7F (56 km/hr, the same speed coded in

CORSIM); CORSIM assessed cruise speed (46 km/hr), and 80% of CORSIM assessed cruise speed (37 km/hr). The 80% of CORSIM assessed cruise speed was investigated to account for the earlier arrival of TRANSYT-7F platoon due to the default β value, since the β value is built in the model and cannot be changed by the user. It is clear from Figure 2 that adjusting the speed to 37 km/hr produced the closest resemblance between the TRANYT-7F and CORSIM arrival patterns.
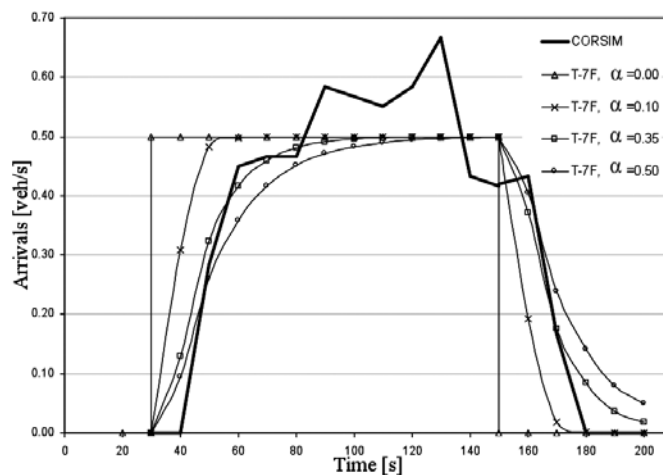

Figure 1: Arrival patterns from TRANSYT-7F with different α values compared to CORSIM results (coded speed = 46 km/hr)
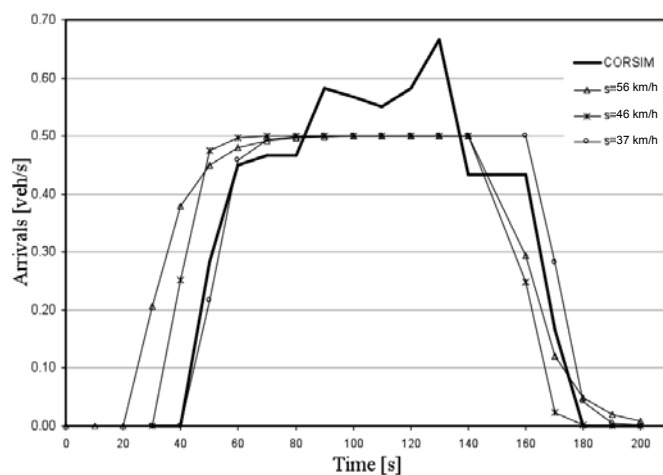

Figure 2: Arrival patterns from TRANSYT-7F with different coded speeds compared to CORSIM results (coded α = 0.1)

In addition to the visual comparison based on Figures 1 and 2, the combination of the α value and coded speed value that produced a TRANSYT-7F arrival pattern that is the closes to that assessed by CORSIM was identified using the root mean square error, as calculated using equation (7) below:
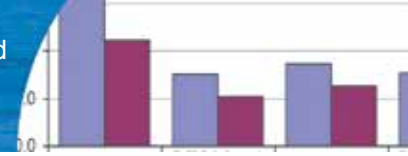
$$X = \sum_n \sqrt{\frac{(x_1 - x_2)^2}{n-1}} \qquad (7)$$

where x_1 and x_2 are the number of vehicles arriving at a given time step in the cycle according to CORSIM and TRANSYT-7F, respectively and n is the number of time steps in the cycle. The results are presented in Table 4. Again, the best solution from Table 4 appears to be produced with an α value of 0.1 and with the cruise speed adjusted to reflect CORSIM assessed cruise speed and further reduced to eliminate the effect of early arrivals in TRANSYT-7F.

Table 4: Sum of the squared mean root sum for different α and speed combinations

Varied parameter	Other parameters	Sum of the squared mean root
α = 0.00	Coded speed is that producing the best results for considered α	0.290
α = 0.10		0.180
α = 0.35		0.222
α = 0.50		0.279
Speed = 56 km/hr	α = 0.10	0.416
Speed = 46 km/hr		0.317
Speed = 37 km/hr		0.180

CORSIM assessment of TRANSYT-7F solutions

To identify the effects of the adjustments of the model parameters in TRANSYT-7F on CORSIM's assessment of the TRANSYT-7F solutions, the plans resulting from the TRANSYT-7F model with and without parameter adjustments were evaluated in CORSIM for the four case studies (Systems A, B, C, and D described in the methodology section of this study). In the figures presented in this section, the "Adjusted speed" refers to the cruise speed as assessed by CORSIM and coded in TRANSYT-7F. The "Corrected speed" refers to further adjustment to the "Adjustment speed" value by multiplying this value by 0.8 to eliminate the early arrivals, as described earlier.

Figure 3 shows the control delays as assessed by CORSIM for signal timing plans produced by TRANSYT-7F with different parameters for System A. This figure shows that adjusting the saturation flow rate, speed, and α values

resulted in significant improvements in the timing plans, as assessed by CORSIM. As shown in Figure 3, the delay increases with the increase in link length with all other parameters fixed. This is because the platoon is more dispersed with longer link lengths and thus, it is more difficult to accommodate all arriving vehicles on green without delaying some of them to the next cycle. This is the same reason that the effects of adjusting the signal timing parameters appears to be more significant for longer links investigated in this study.
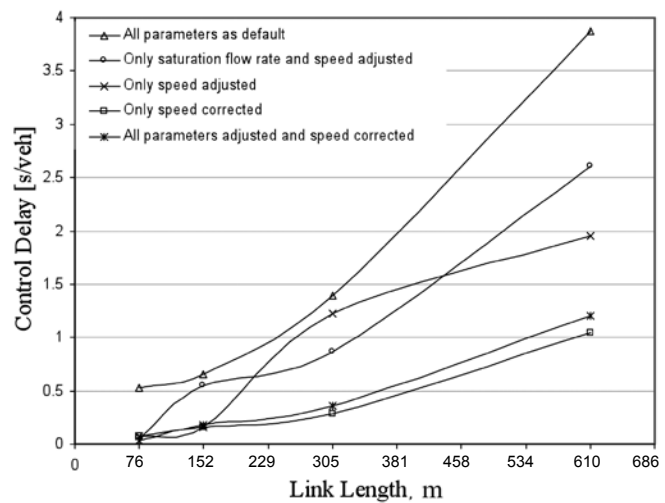

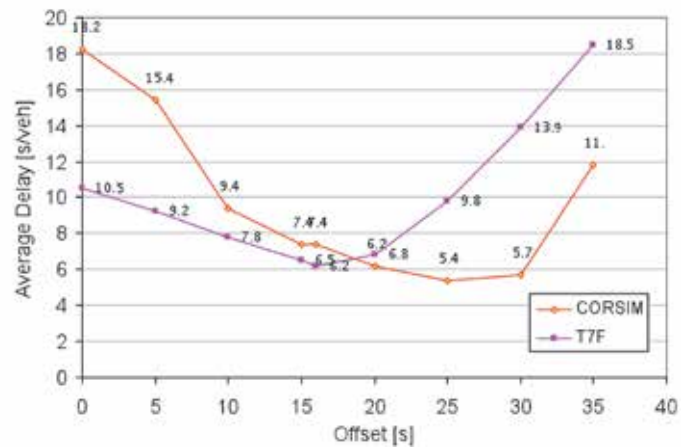Figure 3: Delay improvements due to parameter adjustment for system A

Figure 4: Delay estimation versus offset for link length of 305 m

Figure 4 shows that, for system A, the optimal offset in CORSIM that produced the lowest delay is higher in CORSIM compared to TRANSYT-7F runs with the input speed coded as CORSIM-assessed cruise speed. The results from this figure further indicate the effect of the early arrival in TRANSYT-7F due to the default β value.

The results presented above are for System A, which is a simple hypothetical network with one upstream feeding link. Figure 5 presents the results for System B, which is somewhat more complex than System A in that the examined arrival patterns are for a link that has three feeding upstream links. Due to three different arriving platoons from upstream feeder links, the link delay in System B is higher than System A since it is difficult to accommodate the three platoons on green when they arrive at the downstream signal. Figure 5 again shows considerable improvements (more than 100% improvement) due to the adjustment of TRANSYT-7F parameters.
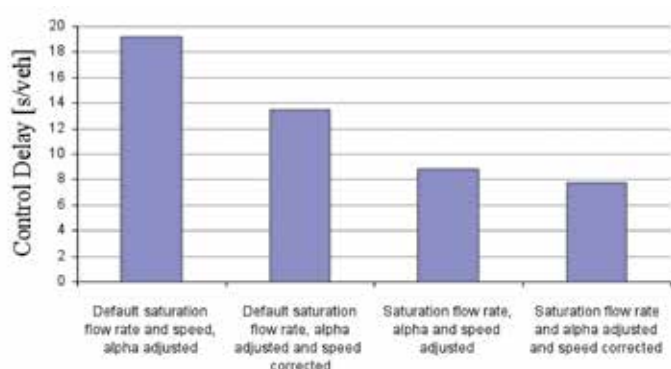

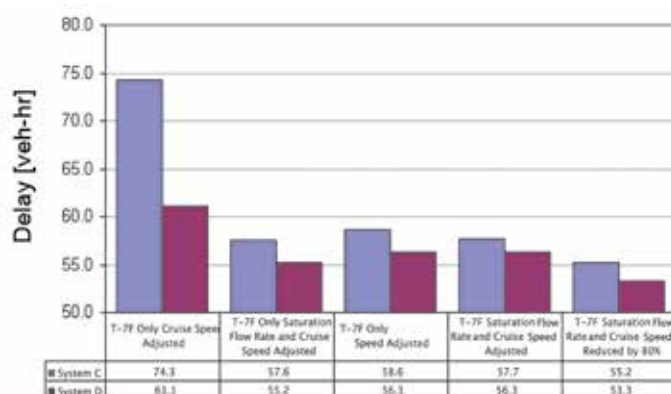Figure 5: Delay improvements due to parameter adjustment for System B

Figure 6: Delay improvements due to parameter adjustment for Systems C and D

Figure 6 shows the reduction in the system-wide average delay as assessed by CORSIM for Systems C and D due to the adjustment of TRANSYT-7F calibration parameters. Systems C and D represent more realistic networks compared to systems A and B discussed above. It appears that the highest improvements in delay were obtained for

these systems due to the adjustments of the saturation flow rates. Additional improvements were obtained due to the adjustments of the other parameters.

Conclusions

Based on the results presented in this study, it can be concluded that adjusting the platoon dispersion parameters (α and β values), coded cruise speed, and saturation flow rate can have significant impacts on the performance of TRANSYT-7F as assessed by CORSIM and also on the correspondence between the arrival patterns assessed by TRANSYT-7F and CORSIM. It appears that using compatible values of saturation flow rates/time headways in TRANSYT-7F and CORSIM, reducing the α value from the default of 0.35 to 0.1, reducing the speed to better correspond with CORSIM assessment of cruise speed, and reducing the speed further to eliminate the early arrival due to the default value of the β parameter will improve the signal timing plans optimized using TRANSYT-7F as assessed by CORSIM. Users of signal timing optimization programs should consider and evaluate such adjustments when optimizing their networks. The default platoon dispersion parameters in TRANSYT-7F may need to be adjusted to reflect the findings of this study.

It is recommended that future studies investigate the effects of adjusting the parameters of additional macroscopic simulation models in TRANSYT-7F and other signal optimization programs, such as the parameters of the shared lane and permitted left turn movement models. In addition, it is recommended that future studies investigate the effectiveness of adjusting the parameters of the oversaturated optimization and simulation models, introduced during the 1990s in TRANSYT-7F. This assessment should be made based on the produced timing plans from TRANSYT-7F for these conditions, as assessed by CORSIM.

Acknowledgement

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