Comparison of optimal signal plans by Synchro & TRANSYT-7F using PARAMICS – A case study

Nedal T. Ratroua, Imran Rezab*

a Professor, Dept. of Civil and Environmental Engineering, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia, E-mail: nratrou@kfupm.edu.sa
b Research Engineer, Dept. of Civil and Environmental Engineering, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia, E-mail: ireza@kfupm.edu.sa

Abstract

TRANSYT-7F and Synchro are two of the most extensively used signal timing optimization softwares in Saudi Arabia. Each of them has its inbuilt objective function to optimize signal plan for intersections, which is different from each other. In this paper, the performance of the optimal signal timing plans developed by TRANSYT-7F and Synchro is compared using the microsimulation software PARAMICS. An urban arterial with three intersections and moderately high traffic in Dhahran, Saudi Arabia is studied. Comparison of the optimized plans is done on the basis of queue length and average delay from the simulated results of PARAMICS. The study showed that the optimized plan by TRANSYT-7F gave better results than the plan by Synchro in terms of queue length and average delay. The study also showed a trend of better optimized signal performance when the timing plans are simulated in their respective simulation model.

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Keywords: TRANSYT-7F; Synchro; Queue length; Optimal signal plan

1. Introduction

Signalized intersections, an essential part of an urban road transportation system, regulate the flow of vehicles in urban areas. Traffic movements through signalized intersections are regulated by the signal system causing vehicular delays due to stops during the red time. Vehicular delay at signalized intersections increases the total travel time in an urban road network resulting in the reduction of speed and cost-effectiveness of the entire
transportation system. Increased travel time results in the degradation of the environment through increased vehicular emission in air and sound pollution. Thus, signal timing plan optimization is inevitable from many perspectives with less consumption of fuel and less environmental pollution being the topmost outcomes.

Various simulation programs and optimization techniques have evolved that aid the traffic engineers in the signal optimization process. TRANSYT-7F and Synchro are two of the most extensively used softwares in Saudi Arabia for signal optimization.

Delay and its derivatives are used as the objective function in most optimization softwares. For example, Synchro optimizes based on the delay and stops while TRANSYT-7F optimization is done based on the Performance Index (PI) that involves delay, progression, stops, and fuel consumption or throughput. User can choose his desired objective function or combination of functions he may need for signal optimization in TRANSYT-7F. Synchro is a user friendly software and one of its biggest advantages is its data conversion features that enable it to export data in other softwares, e.g. CORSIM and TRANSYT-7F. Whereas, the the hill-climbing and genetic algorithm (GA) methods embedded in TRANSYT-7F make it a better optimization model [1].

Yang [2] compared the timing plans optimized by TRANSYT-7F, PASSER II and Synchro using CORSIM simulation software. From this particular study, he concluded that TRANSYT-7F always produced longer cycle lengths; PASSER II works better for intersections with unbalanced volumes and CORSIM was a very good tool to evaluate timing plans. Chaudhury and Chu [3] conducted a research to compare Synchro, TRANSYT-7F and PASSER II. It showed that with an increased arterial size, PASSER II would provide better two-way arterial progression than Synchro. Kim [1] compared the performance of optimization ability of Synchro and TRANSYT-7F using CORSIM. Only percent stops of TRANSYT-7F showed better result while delay, throughput and system speed of Synchro showed better results from his study. Zhung and Xie [4] also compared the optimized signal timing plans by PASSER V, TRANSYT-7F and Synchro based on CORSIM simulation. They found that Synchro and PASSER V performed better than TRANSYT-7F in terms of simulated network-wide and arterial measure of effectiveness (MOEs).

The specific objective of this study is to compare the performance of optimized signal plans produced by Synchro and TRANSYT-7F using the microscopic traffic simulation software PARAMICS. Even though the optimization softwares are having their own simulation modules, simulating optimal plans developed by Synchro and TRANSYT-7F using the same model, namely PARAMICS, ensured unbiased comparison and fair conclusions.

2. Software description

As this study intended to make a comparison between the optimization results of TRANSYT-7F and Synchro, a brief review of the optimization techniques of the two softwares is briefly discussed in the next section followed by a short narration about the microscopic simulation software PARAMICS.

TRANSYT-7F uses a macroscopic-deterministic model for analyzing and optimizing signal timings on arterials and networks. It uses a combination of hill-climbing and Genetic Algorithm (GA) based optimization methods. It is primarily designed to select signal timings that produce minimum system delay and stops. In TRANSYT-7F, the optimization objective function is reflected by the “performance index” (PI) [5]. It offers numerous PI’s to choose from, which can reflect anything that the user desires including delay, progression, stops, fuel consumption, queuing, and throughput. TRANSYT-7F generates second-by-second flow profiles of vehicles on all links in the network during its optimization process. Then, it analyzes these profiles to determine measures of effectiveness (MOEs). TRANSYT-7F has two delay-based traffic models: link-based and step-based. It has been extensively validated by its users all over the world and accepted as an efficient model. TRANSYT-7F performs exhaustive search for cycle length. For each cycle, it starts by calculating equal saturation splits and applying a hill-climbing method to optimize signal offsets and splits [5]. For this reason, its final results depend on the base timing plan supplied by the user.

Synchro is a delay-based program for analyzing and optimizing timing plans for arterials and networks. Its objective function also minimizes stops and delay by applying penalties for the MOEs [4]. Synchro’s traffic model is similar to the link-based model in TRANSYT-7F. It optimizes cycle length by analyzing all cycles in the defined range. Optimization of offsets is divided in multiple stages, during which the step sizes depend on the optimization level selected by the user [6]. Unlike TRANSYT-7F, Synchro’s traffic model does not consider platoon dispersion.
The program calculates cycle length and green splits by Webster’s method and delay by the method used in the Highway Capacity Manual (HCM) [7]. Synchro optimizes all signal-timing parameters for pre-timed and actuated signals. It has an excellent user friendly interface that provides features to easily fine-tune a timing plan. Because of its ease of use, many engineers use it as an input processor for TRANSYT and CORSIM [6].

PARAMICS is one of the most powerful microscopic urban and freeway traffic simulation software that is used to model the movement and behavior of individual vehicles in road networks. PARAMICS was developed on a sophisticated microscopic car following and lane changing model, dynamic and intelligent routing, inclusion of intelligent transportation systems and the ability to interface with the real time traffic input data sources. The animation generated in PARAMICS allows the user to check the appropriateness of the coding of the network and traffic flow visually. The user can also check queue spillback, insufficient storage and weaving problems. The program generates reports on various MOEs for network assessment [8].

3. Data collection and study area

The selected study area is an urban arterial of ideal geometry in accordance with AASHTO policy [9]. The arterial has low friction due to pedestrian and parking in the city of Dhahran, Saudi Arabia. The mainline street is Prince Faisal Bin Fahd Road with three signalized intersections connecting Dhahran highway (by a diamond intersection), Abu Ubaidah street and King Saud road as shown in figure 1. The mainline street consists of three through lanes and one left turning bay at the middle intersection. The network is located in a commercial zone with sufficient off-street parking facilities for each zone of trip attraction. Traffic volume, speed, queue lengths and signal timing plan data were collected at the intersections from 8:30 AM to 9:30 AM on a weekday by means of manual counting and automatic counter. The traffic volume at the study time was moderately high but not reaching saturation condition. At the time of study, all of the investigated intersections were not coordinated and operated as an independent isolated intersection.

4. Research methodology

The study methodology involves optimization of signal timing plans in TRANSYT-7F and Synchro using the same volume data. Each optimum plan was then simulated using microscopic traffic simulation model PARAMICS as a common yardstick for comparison. Then the optimized signal plans developed by TRANSYT-7F and Synchro were also simulated by their respective simulation model for further comparison. The default Disutility Index in TRANSYT-7F which minimizes delay and stops in its optimization objective function was used to find the optimal
plan [5]. The default percentile delay and stops method was used for signal plan optimization in Synchro [10]. The default objective function of each model was used since most practitioners in the study area tend to use this for convenience.

5. Signal optimization

TRANSYT-7F was calibrated by Ratrout and Olba [11] for a similar network just 4.2 km away from the studied network. They calibrated the model by changing the model parameter Platoon Dispersion Factor (PDF) to match the selected MOEs. As the studied arterial was not physically coordinated, it was chosen to optimize the intersection signal timing plan without any offset in order to make the model compatible with the observed field plan. Therefore, no offsets of the intersections were derived from TRANSYT-7F. The signal plan was also optimized in Synchro with the same hourly volume. Ratrout and Olba also attempted to calibrate Synchro in the same study area but they could not calibrate it in a meaningful way [11]. In this study, the same base model setup was used which Ratrout and Olba used for their case in Synchro. The optimized signal timing plan in TRANSYT-7F and Synchro is given in table 1.

<table>
<thead>
<tr>
<th>Intersection #</th>
<th>Direction</th>
<th>Optimized plan in TRANSYT-7F</th>
<th>Optimized plan in Synchro</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Green (S)</td>
<td>Cycle Length (S)</td>
</tr>
<tr>
<td>1</td>
<td>NB</td>
<td>13</td>
<td>120</td>
</tr>
<tr>
<td>(Exit from KFUPM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EB</td>
<td>21</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>37</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>WB</td>
<td>29</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>NB</td>
<td>12</td>
<td>130</td>
</tr>
<tr>
<td>(Prince Faisal–Abu Ubaidah)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EB</td>
<td>43</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>WB</td>
<td>46</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>EB</td>
<td>13</td>
<td>115</td>
</tr>
<tr>
<td>(Prince Faisal–King Saud-1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>23</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>WB</td>
<td>64</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>NB</td>
<td>18</td>
<td>115</td>
</tr>
<tr>
<td>(Diamond Interchange)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EB</td>
<td>41</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>WB</td>
<td>41</td>
<td>16</td>
</tr>
</tbody>
</table>

To make compliance with the observed signal plan, yellow time and all red were kept to be 3 and 2 seconds, respectively, for all signal phases.

6. Results and discussion

Optimizing a signal plan mostly depends on the objective functions that the model minimizes. Even though delay and number of stops are the primary parameters used by both TRANSYT-7F and Synchro to optimize the signal, yet there were differences in the optimized cycle length for each of the intersections, simply because the objective function and the optimization technique used are not identical. The maximum difference of cycle length was 69% in the third intersection and a minimum of 13% in the second intersection. Average cycle length of TRANSYT-7F and Synchro was 122 seconds and 111 seconds, respectively. TRANSYT-7F allocates more time to the main corridor
(East-West) than minor streets. However, the ratio of time split in the main corridor to minor streets by both TRANSYT-7F and Synchro is equal to 63:37.

The same studied network was coded in PARAMICS with the necessary arrangements and Origin-Destination (OD) matrix which was developed by a specialized module estimator within the model. PARAMICS simulation model was recently calibrated and successfully used in the same arterial [8]. PARAMICS was used to simulate the studied network with the existing (non-optimal) signal plan.

Further to that, another two distinct simulations were run in PARAMICS using the optimized signal timing plan by TRANSYT-7F and Synchro. The queue length at the major arterial was obtained from the simulation output for comparison.

6.1. Queue length comparison

Queue Length is one of the important performance measures for evaluating a network. Measuring the queue length in the field is also easier than other MOEs. Queue Length was measured in the field and compared to the simulated value. Figure 2 shows the comparison between the observed Queue Length and simulated Queue Length in PARAMICS. The comparison was made only to justify the use of PARAMICS microsimulation model in this paper. Figure 2 shows that the simulated and observed queue lengths are comparable with a maximum difference of 10%.

Since QL from PARAMICS simulation results is comparable to the observed QL in the field, it was used as a common yardstick to compare the optimized signal timing plan by TRANSYT-7F and Synchro. The existing signal plan and the optimal timing plans developed by TRANSYT-7F and Synchro were simulated by PARAMICS. The queue length obtained by PARAMICS for each plan was studied. Figure 3 depicts the comparison among the queue lengths in PARAMICS with the observed plan, TRANSYT-7F plan and Synchro plan.

Figure 3 shows that the optimized signal plan by TRANSYT-7F performs better than Synchro in three out of four cases in terms of queue length comparison. The maximum difference of queue length between TRANSYT-7F and Synchro plan is 53% at the first intersection while the minimum difference of queue length was 5% at the second intersection (Westbound). The queue length from the Synchro plan in the first intersection was significantly higher than the TRANSYT-7F plan. The geometry of the first intersection was complex and difficult to model in Synchro in contrast to TRANSYT-7F. This inexact coding of the intersection in Synchro might be the main reason for the high difference between QL resulting from Synchro and TRANSYT-7F. However, the queue length produced in the other two intersections was reasonably comparable. The Eastbound queue length of the second intersection for TRANSYT-7F was only higher by 1 vehicle per cycle length than Synchro. The comparison reasonably attains its validity as PARAMICS simulation was considered to be the common yardstick. The better performance by
TRANSYT-7F in terms of queue length indicates that a better traffic system has been achieved with more vehicles passing the stop line without being stopped. As all the other factors remain the same while running the simulation in PARAMICS, the difference in queue length must be attributed to the embedded model by which the signals are optimized.

The optimized signal plans developed by both TRANSYT-7F and Synchro were made to run in their respective simulation program and the Queue Length from the simulated outputs were compared. Comparing figure 4(a) and figure 4(b), it can be seen that both TRANSYT-7F and Synchro produced slightly better results when they are simulated with their respective optimized signal plans. It is also interesting to note that the optimal plan by Synchro was simulated in TRANSYT-7F and vice versa. It was found that each model tends to perform better when its optimal plan is simulated in the same model. These findings augment the procedure of comparing the simulated optimal plans of TRANSYT-7F and Synchro by PARAMICS. It is also worth mentioning that the simulation of TRANSYT-7F plan by the same model is comparable to the PARAMICS simulation of the same plan depicted in figure 4(a). On the other hand, Synchro simulation was not that good when compared to the PARAMICS simulation shown in Figure 4(b).

Fig. 3 Comparison of Queue Length simulated with different signal timing plans in PARAMICS

Fig. 4 (a) Comparison of QL with TRANSYT-7F plan; (b) Comparison of QL with Synchro plan
6.2. Delay comparison

The optimal signal plans of TRANSYT-7F and Synchro were simulated in PARAMICS and the resulting network link delay was compared. Five different runs of simulation were performed with different seed values in PARAMICS. In each run, the same seed value was used to simulate the TRANSYT-7F and Synchro plans. The result of the simulation is shown in table 2.

Table 2. Comparison of delay between TRANSYT-7F plan and Synchro plan

<table>
<thead>
<tr>
<th>Link Delay (Seconds)</th>
<th>TRANSYT-7F Plan</th>
<th>Synchro Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average Delay</td>
<td>Average Delay</td>
</tr>
<tr>
<td>Run 1</td>
<td>6.30</td>
<td>8.66</td>
</tr>
<tr>
<td>Run 2</td>
<td>6.16</td>
<td>8.59</td>
</tr>
<tr>
<td>Run 3</td>
<td>6.18</td>
<td>8.61</td>
</tr>
<tr>
<td>Run 4</td>
<td>6.23</td>
<td>8.60</td>
</tr>
<tr>
<td>Run 5</td>
<td>6.44</td>
<td>8.72</td>
</tr>
</tbody>
</table>

6.3. Statistical analysis

A t-test was conducted to know if the differences in delay from Synchro and TRANSYT-7F are significant at 95% confidence level. As the sample statistics have paired data sets as shown in table 2, the paired t-test was used. Basic paired sample t-test is as follows:

\[ t = \frac{d_m}{\frac{S_d}{\sqrt{n}}} \]  

where,

- \(d_m\) : the mean of differences in delay (delay of Synchro – delay of TRANSYT-7F)
- \(S_d\) : the standard deviation
- \(n\) : the sample size

\(H_0 : d_m = 0\) and \(H_1 : d_m \neq 0\), with 4 degrees of freedom at 95% confidence level.

The parameter tested is the average delay of the whole network according to the results of PARAMICS simulation using the optimal timing plan of each model. The t-value resulting from equation 1 was calculated to be 85.80, which is significantly greater than the critical t-value of 2.78 at 95% confidence level. This means that the delay per link from TRANSYT-7F and Synchro models are statistically not equal. In fact, the delay from TRANSYT-7F is smaller than the delay from Synchro. Therefore, it can be said that the optimization capability of TRANSYT-7F is better than that of Synchro in terms of average delay for this particular arterial under the studied volume conditions.

7. Conclusion

A comparison of the optimized signal timing plans by TRANSYT-7F and Synchro was conducted to evaluate which model works better for a specific road network. To compare the two optimization plans, a common yardstick in the form of a different microsimulation software PARAMICS was used to eliminate any kind of bias. The queue length simulated by PARAMICS was comparable to the observed ones at the studied intersections. The difference between observed and simulated queue length was below 10%. This study revealed that the optimized plan by TRANSYT-7F showed better result than the plan by Synchro when the queue length and delay were compared. However, other measures of effectiveness (MOEs) such as stops, fuel consumption and throughput were not
examined to justify this statement. In addition, it is worth mentioning that the study was done in a small network with only three intersections with moderately high traffic volume and consequently, the result of this study cannot be generalized to other areas or at different levels of traffic volume. The study also shows that there are differences when the optimal plans are simulated in their respective simulation model and PARAMICS. This should be seriously considered in any comparison study like this.

Acknowledgements

The authors wish to acknowledge the financial support provided by the Deanship of Scientific Research (DSR) of King Fahd University of Petroleum & Minerals, Saudi Arabia in carrying out this study under the project titled “PARAMICS Model Development for Local Traffic Conditions in Saudi Arabia” (Project No. IN111047).

References