Improved Graphic Techniques in Signal Progression

CHARLES E. WALLACE and KENNETH G. COURAGE

ABSTRACT

The results of several research studies into graphic representations of traffic signal system settings and traffic flow are presented. The research began with the fundamental time-space diagram, which is universally understood by traffic engineers, and also with flow diagrams from the TRANSYT model. Three specific departures from these basic techniques are presented, which include time-location diagrams, forward progression opportunities, and platoon progression diagrams. All of these techniques apply to linear arterial systems or subsystems. Another graphic technique that applies to a network of coordinated signals is then discussed: signalized network animated graphics. Interpretation of signal timing-optimization strategies, namely maximal bandwidth optimization, is discussed using the platoon progression diagram technique. This analysis demonstrates the pitfalls of the maximal bandwidth approach, thus demonstrating the power of the analysis technique.

Traffic engineers have traditionally analyzed the quality of traffic flow in coordinated traffic signal systems by either direct field measurement or by the use of off-line analysis techniques. Field studies are typically the superior approach to such analysis; however, the alternatives that may be evaluated by field studies are limited to those that the traffic engineering agency can actually install in the system. The field study approach is not conducive to design because of this limitation.

Off-line computational techniques support a wide range of designs and design strategies without requiring field implementation and evaluation studies. Although the assessment of traffic flow using such techniques is limited by the assumptions and limitations of the selected technique, their use can nonetheless dramatically increase the productivity of the traffic engineering agency.

Off-line techniques generally consist of numerical estimates of the pertinent measures of effectiveness (MOEs) and graphical representations. Numerical estimates of MOEs are typically accomplished by deterministic, or analytical, techniques; by simulation of traffic flow; or by a combination of these two. Such techniques vary considerably in their realism or accuracy, depending on the theoretical basis of the estimates; but, more significantly, they are simply numbers (e.g., delay, number of stops, fuel consumption, bandwidth) that do not offer any visual perception to the analyst as to the quality of traffic flow.

On the other hand, graphical techniques do give a picture of the perceived quality of traffic flow. Although it is true that, ultimately, MOE estimates (or even field measures) are used to quantify improvements, the graphic presentations can be of great assistance in assessing the quality of traffic flow as part of the design decision process.

A number of graphical representations of traffic signal timing and traffic flow that can be extremely useful analysis and evaluation tools for the practicing traffic engineer are presented here. First, the time-space diagram, which is universally known and used by traffic engineers, is presented, and later three specific departures that enhance the utility of this familiar graphical technique are discussed. A second existing technique for illustrating simulated traffic flows is also reviewed.

TIME-SPACE DIAGRAMS

For coordinated systems, the classical graphic presentation of traffic signal timings is the time-space diagram (TSD). A TSD, as shown in Figure 1, illustrates the relationship of a series of traffic signals in a coordinated system by showing the signal timing on the artery and the offset relationships. When the through bands are drawn, the slopes of the bands illustrate the desired speed(s) of the through bands. This is the inherent use of TSDs: to illustrate the perceived progression through a system of traffic signals.

TSDs have been produced manually for more than 50 years. Until recently, they were virtually the only method of optimizing progression on arterial routes. Given the complexity of the task, it is logical that computerized techniques would replace the manual analysis. This has, in fact, happened gradually over the past 20 years.

Computer models such as PASSER II 80 (1), MAXBAND (2), TRANSYT-7F (3), and SIGOP II (4) are among the more popular models that produce TSDs. The first two models have as their explicit objective function the maximization of through bandwidth.

The TSD presents a gross oversimplification of the traffic flow process. Its primary disadvantage as an analysis tool is that no consideration is given to the actual traffic demand. As a result, time-space or so-called maximal bandwidth-based designs may result in apparently satisfactory green bands, but in reality traffic would only be progressed into the rear of standing queues.

The usefulness of TSDs is also practically limited to linear arterials. Several attempts have been made to develop three-dimensional TSDs, but this practice is extremely laborious. Furthermore, three-dimensional TSDs are difficult to interpret. Thus the usefulness, and particularly the flexibility, of standard TSDs for networks is limited. TSDs may also be extremely lengthy for long arterials.

TRAFFIC FLOW PATTERNS

The concept of using traffic flow distributions to simulate traffic flow was introduced by Robertson (5), who described traffic flow as falling into two basic patterns, or profiles (simplified here):

1. The arrival pattern, which is the periodic flow rate of traffic arriving at a reference point on a street, which is usually the stop line; and
2. The departure pattern, which is the periodic rate of flow departing the stop line, subject to the signal display facing the traffic. [If a queue exists at the start of effective green (i.e., green start plus lost time), it departs at the maximum

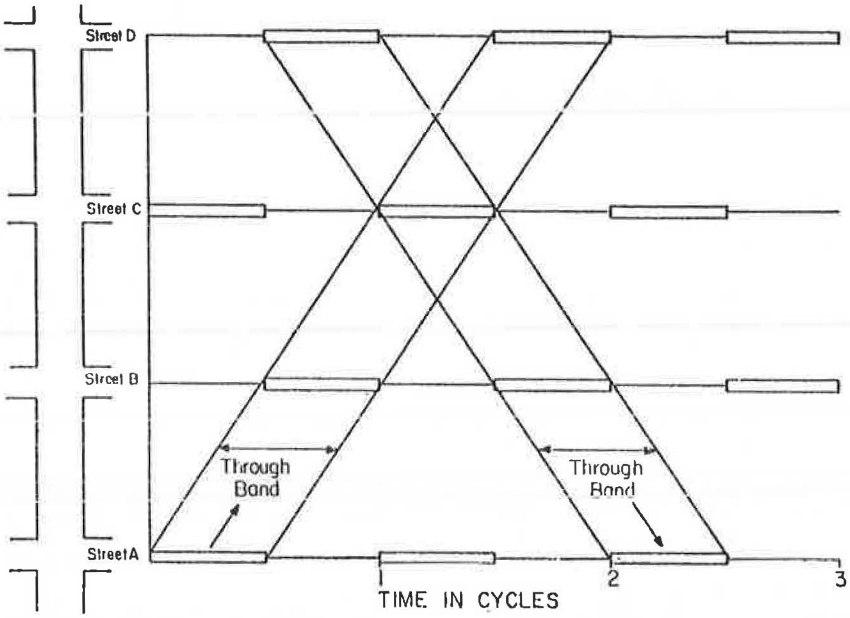
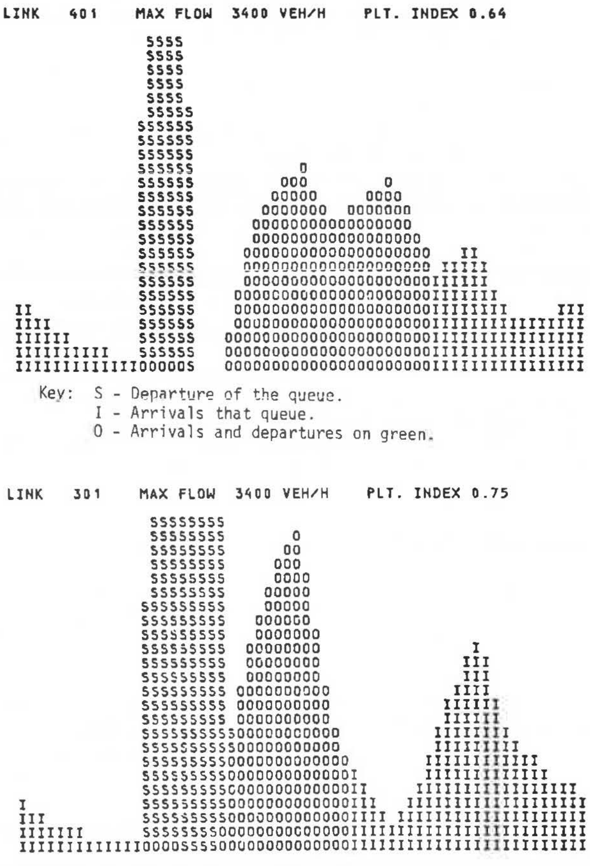


FIGURE 1 Typical TSD.

rate, or saturation flow and arrivals continue to add to the back of the queue. Once the queue has dissipated, departures equal arrivals and are not delayed.]

These patterns are illustrated in Figure 2.

This concept has been implemented in the Traffic Network Study Tool (TRANSYT) model (5), which has further evolved to versions TRANSYT-7F (3), which is used in the United States, and TRANSYT-8 (6), which is available from the Transport and Road Research Laboratory.



LINK 401 MAX FLOW 3400 VEH/H PLT. INDEX 0.64

Key: S - Departure of the queue.
I - Arrivals that queue.
O - Arrivals and departures on green.

LINK 301 MAX FLOW 3400 VEH/H PLT. INDEX 0.75

FIGURE 2 Typical flow pattern diagram.

The flow profile represents a snapshot of traffic flow on a single approach, or link, for one signal cycle; thus it represents the average traffic behavior that might exist over a longer period of, for example, 1 hr. This is the distinct advantage of this form of graphic display, because the simulated traffic flows, arrivals, and departures are actually shown. When TRANSYT is optimized to minimize stops and delay (or excess fuel consumption), it is usually trying to position the green interval on every link to clear the queues before the arrival of the moving platoons, provided the proper stop penalty is used. The same purpose is served by the queue clearance options in the PASSER II 80 and MAXBAND models, but in TRANSYT the adjustment is made explicitly.

Of the available graphic techniques, these profiles best visualize the quality of traffic flow. For example, Figure 2 shows two links, where (a) the traffic platoon arrives after the queue has dissipated, and (b) the platoon arrives just at the departure of the queue. In both cases there is minimal delay to the primary platoons, but if this offset relationship was plotted on a TSD, the band would appear to be too fast.

The disadvantages of this technique are as follows.

1. Some traffic engineers find the profiles difficult to interpret because the vertical scale is a flow rate. (The horizontal scale is time in steps of the cycle.)
2. The profiles are at the stop line at each link; thus the system interrelationships are difficult to visualize, although they can be aligned to show traffic progression down (southbound) one side of the computer output and up (northbound) the other side.
3. Similarly, the signal timing parameters are not readily apparent, and optimization by TRANSYT will typically result in offsets that appear to be too early because of the queue clearances noted previously. Engineers accustomed to TSDs do not visual-

ize the progression because the apparent speed is too fast.

With regard to the last point, it appears that the concept of through bands representing progression is misleading, and a better interpretation of satisfactory progression is the uninterrupted propagation of platoons. This is discussed in more detail later.

INNOVATIVE TECHNIQUES

In recent years several new concepts of traffic progression and the graphical representation thereof have emerged, particularly for coordinated systems. These are described in the following subsections.

Time-Location Diagrams

As mentioned earlier, TSDs can be lengthy for long arterials. This not only wastes paper, but also causes problems with report reproduction. More significantly, TSDs generally do not fit on video monitors, and the increasing use of computerized tools would render this a disadvantage.

The progression speed (i.e., the slope of the bands) is usually given and is therefore of less concern than the bandwidth, which is the MOE. A TSD can be easily modified by correcting the plotted offset to account for travel time, such that the slope of the band becomes zero at the desired speed. The plot can then be rotated from link to link so that a horizontal line (assuming the vertical axis is time and distance is on the horizontal) would represent the desired speed, or zero slope. The distance between intersections is no longer meaningful, so the diagram can be collapsed. Thus the vertical axis remains time, but only the relative order of intersections is important on the horizontal scale.

When this is done for both directions of travel, two so-called time-location diagrams (TLDs) can be plotted next to one another. The TLD technique was first reported by Wallace and Courage (7), and an example is shown in Figure 3, which was installed in a modified version of TRANSYT-6C (8). This TLD represents a design based on PASSER II's bandwidth optimization.

More significantly, the TLD concept has been incorporated into the arterial analysis package (AAP) (9) microcomputer routine SPAN (10). By using either keyboard entry on an APPLE computer or transfer of special outputs of the AAP from the mainframe computer to the APPLE, a TLD can be plotted directly on the monitor, as shown in Figure 4.

By observing the TLD and recalling that zero slope represents the desired speeds, progression in the classical sense is visualized as a horizontal tunnel of green through all the intersections for both directions. This diagram can be manipulated to change offsets to improve progression if desired.

The TLD is a simpler tool to use than the TSD because it is compact and the quality of progression

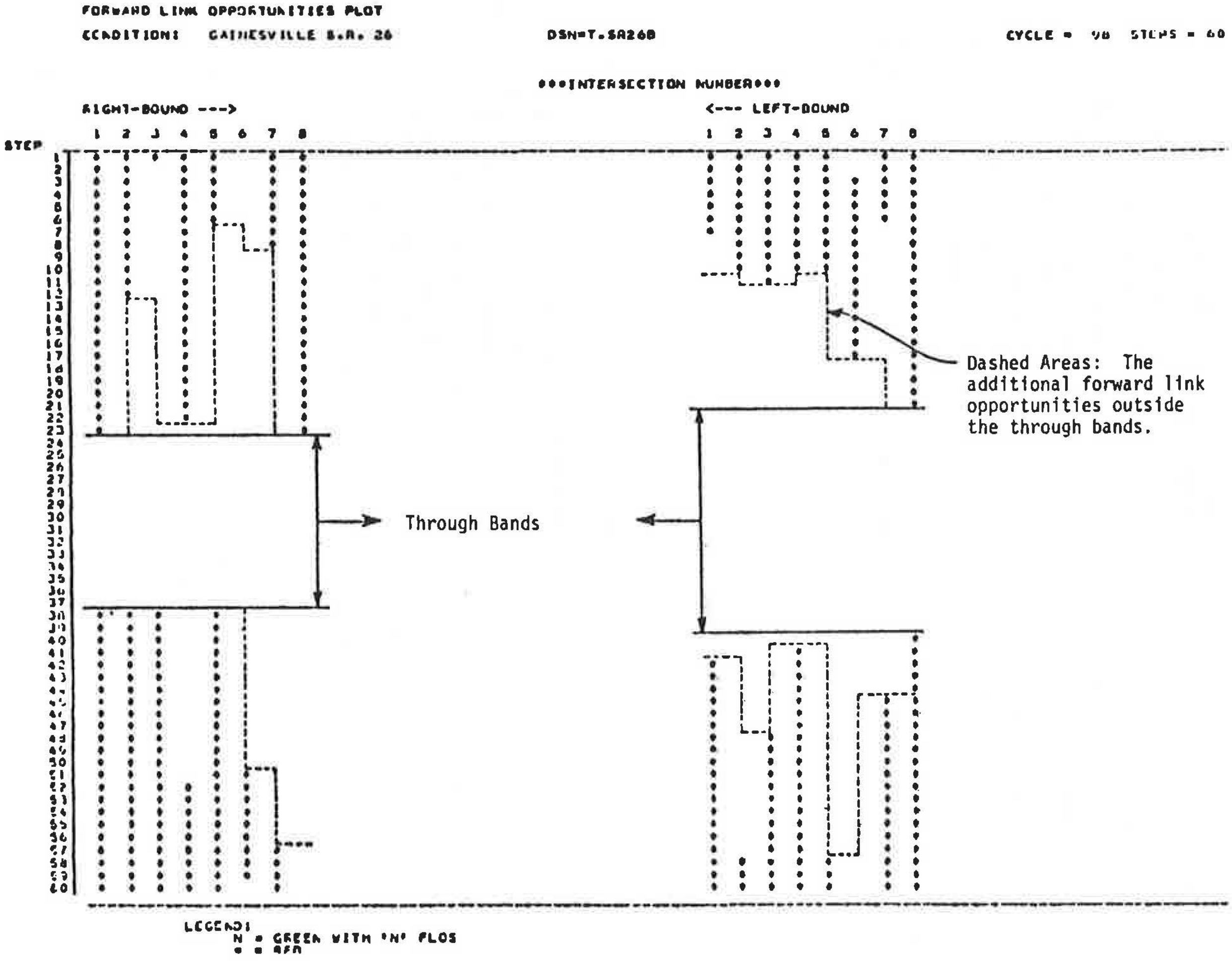


FIGURE 3 Printed TLD.

is much more apparent visually. It is particularly useful for visualizing progression throughout a portion of the system and for identifying critical signal locations.

Forward Progression Opportunities

The concept of the TLD was extended by the authors to improve on the basic concept of traffic signal design based on time-space relationships, particularly in computerized optimization models. Maximal bandwidth models such as PASSER II 80 and MAXBAND are only concerned with through bands. Some intersections are noncritical, and their resulting offsets will not be assigned with any specific objective in mind. Furthermore, there are often progression opportunities that do not exist over the entire length of an artery but do exist in short sections where progression could be beneficial.

The concept of forward progression opportunities (PROS) was developed to overcome this deficiency (7,8). A forward progression opportunity is simply the opportunity presented to the motorist arriving during various times in the cycle to travel forward on one link of an arterial system without being stopped by a signal at either end of the link. PROS can thus be quantified by examining the progression opportunities periodically throughout the cycle and summing them. Signal timing optimization can likewise be based on maximizing PROS. The difference between a maximal bandwidth design and a PROS design on the same facility (optimizing offsets only) clearly illustrates the advantage of the PROS approach, as seen in Figure 5 (i.e., compare the dashed areas representing PROS with the similar areas in Figure 3).

The PROS concept has been implemented in TRANSYT-6C and has been proposed as an enhancement to TRANSYT-7F and the AAP.

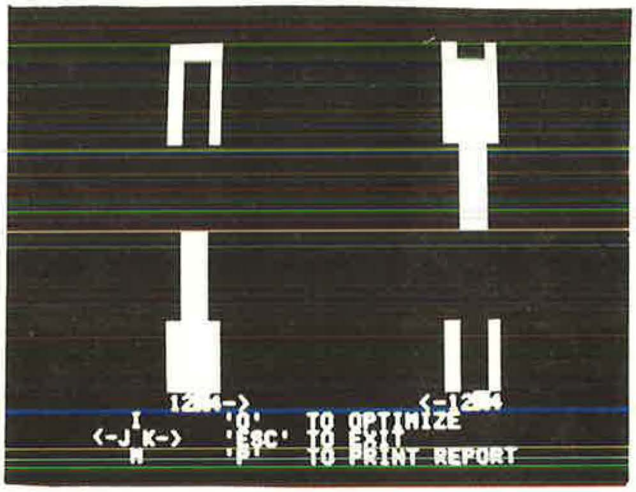


FIGURE 4 Computer plot of TLD.

Platoon Progression Diagram

In the earlier section on existing graphics tech-

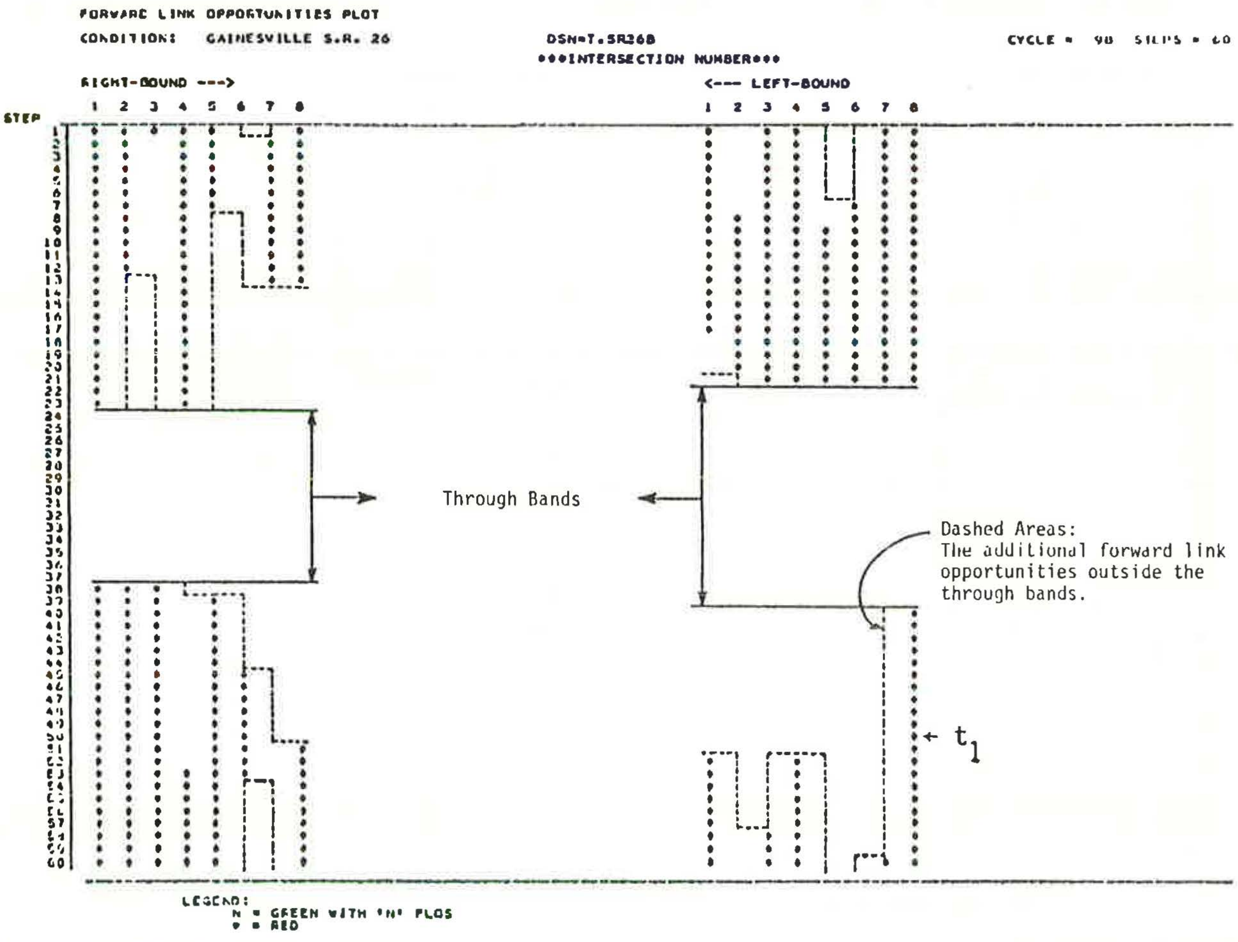


FIGURE 5 TLD from a PROS optimization.

niques, TSDs and platoon profiles were introduced, and the relative advantages and disadvantages of each were given. A review of these techniques suggests that the disadvantages of one approach were advantages of the other to some extent. The logical question is, Why not combine the two?

Considering that both require two dimensions (i.e., time versus distance and flow rate versus time), a total of three dimensions are needed; therefore, a method is required to represent the third dimension in a two-dimensional graphic to display on a monitor or to print. The approach taken by the authors was to plot a standard TSD in two dimensions and express the platoon profiles as a density function. A platoon profile can be sliced into several relative levels of flow rate as shown in Figure 6, where the higher the flow rate, the denser the area to be plotted.

A microcomputer program was developed to accept various output data readily available in the TRANSYT model (which includes timings, saturation flows, platoon dispersion factors, and the departure patterns on each link), and to use these data to produce a platoon progression diagram (PPD) display. The program applies TRANSYT's platoon-dispersion model every 50 ft along the artery and converts the propagated profile to a density function, normalized to the maximum flow rate, which is then plotted. A simplified PPD is shown in Figure 7. The dark areas departing from upstream intersections represent flow

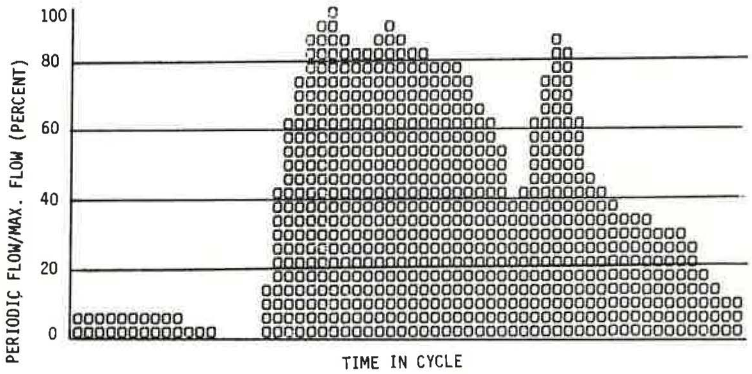
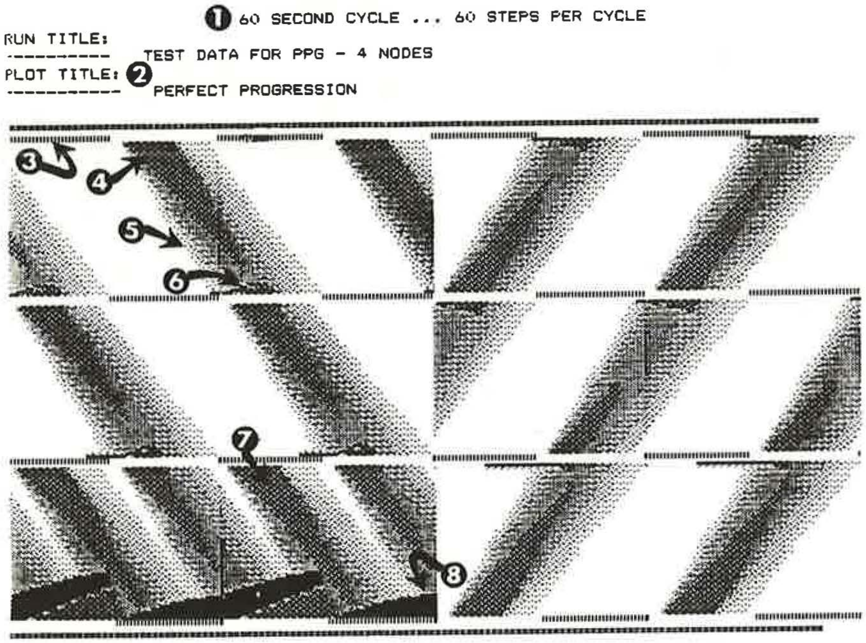


FIGURE 6 Flow profile illustrating density function.



```
                    ❶ 60 SECOND CYCLE ... 60 STEPS PER CYCLE
RUN TITLE:
----------    TEST DATA FOR PPG - 4 NODES
PLOT TITLE: ❷
-----------    PERFECT PROGRESSION
```

❶ The cycle length and step size are TRANSYT inputs.

❷ The titles are also entered into TRANSYT.

❸ SIGNAL STATUS - (red or green) is shown just like a time-space diagram.

❹ The platoon is saturated as it leaves the intersection.

❺ The platoon spreads out as it progresses down the street.

❻ A small queue builds up here because a few vehicles have been stopped on the red.

❼ This platoon results from turning traffic entering the link on the cross street green:

❽ This large queue builds up because the link volumes are near capacity.

FIGURE 7 Typical PPD.

at or near the maximum, whereas the lighter areas are flows of lesser magnitude, perhaps undelayed arrivals. As the platoon travels downstream it disperses, so that the length of time to which the highest flow rate applies will decrease; thus the dark areas become narrower and eventually disappear. The lighter areas appear to diverge, again representing the physical lengthening of the platoon in time as it disperses. The PPD therefore graphically shows the platoon behavior over the entire block or link length. Cross-street traffic is shown as platoons departing upstream in the red of the arterial.

As the traffic approaches the downstream intersection and if it arrives on red, it builds a queue as shown in Figure 7. The queuing model is based on input-output calculations and assumed vehicle lengths. Platoons that are not delayed pass through on green.

This graphic has the following advantages:

1. The best features of TSDs and platoon profiles are combined;
2. Traffic progression (as opposed to green time alone) is clearly represented;
3. The effect of queuing is clearly shown;
4. The point made earlier (i.e., the desirability of clearing the queue before the arrival of the platoon) is made obvious; and
5. The graphic is easier to interpret than flow profiles, particularly in terms of system performance, and it shows the pitfalls of a straight bandwidth approach.

The outputs to this program are directly available from Release 3 of TRANSYT-7F. The PPD shown in Figure 7 was produced by the BITE (11) program.

Signalized Network Animated Graphics

It was also noted earlier that TSDs for networks are extremely difficult to construct and perhaps even more difficult to interpret. The problem again is the need for three dimensions where only two are available on a monitor or on a printed page. One approach to solving this dilemma is to actually use three dimensions, where time is the third dimension. Imagine a TSD on a linear route with the through band drawn. If a slice or cross section of the band is drawn on the distance axis every short increment of time, the physical location of the green band can be located on the route as a function of time. If the green band was superimposed over the street itself, and subsequent frames of such a picture were viewed in sync, the band would appear to move along the route.

The same representation can also be shown on a network of streets, and the bands would then be moving along all streets in the appropriate directions. This concept was first implemented by Courage (12) by using a computer output microfilmer, an expensive machine that has now become obsolete.

The concept remains quite compelling, and with the power of microcomputers and computer graphics, the authors have currently developed a microcomputer-based model called signalized network animated graphics (SNAG), which will be economically viable for widespread use. This model uses an IBM Personal Computer with medium-resolution color graphics. Sample frames showing the display at three points in the cycle are presented in Figure 8.

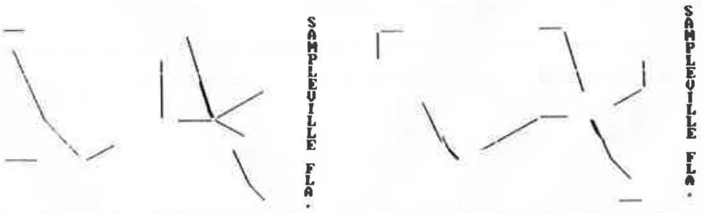
Another extremely important advantage of the SNAG animated network is its public appeal. The concept is intuitively simple to understand and can be used as a public relations tool to demonstrate to the general public and administrative officials how effective a completed or proposed traffic signal system improvement project has been or will be.

Considering the earlier comments about the usefulness, or rather limitations, of TSDs per se, a further extension of the SNAG concept will be to animate the movement of traffic platoons rather than green bands. This development should prove far more useful to the traffic engineer.

USING GRAPHICS TO INTERPRET DESIGN EFFECTIVENESS

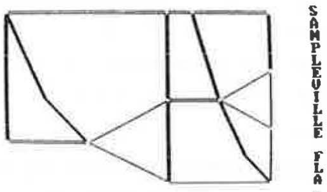
The foregoing discussions have briefly described several commonly used and several innovative graphic tools for analyzing signal timing and traffic flow. It is noteworthy to repeat that traffic signal system timings have traditionally been based on time-space relationships by using manual methods or computer models like PASSER II 80 and MAXBAND. Recently, however, an increasing number of practitioners are shifting to strategies that optimize system efficiency, using models such as TRANSYT-7F and SIGOP III.

This shift in strategies holds merit, and an ex-



A. Progression Band Positions At the Beginning of Cycle

B. Progression Band Positions a Few Seconds After the Beginning of Cycle



C. Full Network Plot

FIGURE 8 Sample frames of three points in cycle from the SNAG program.

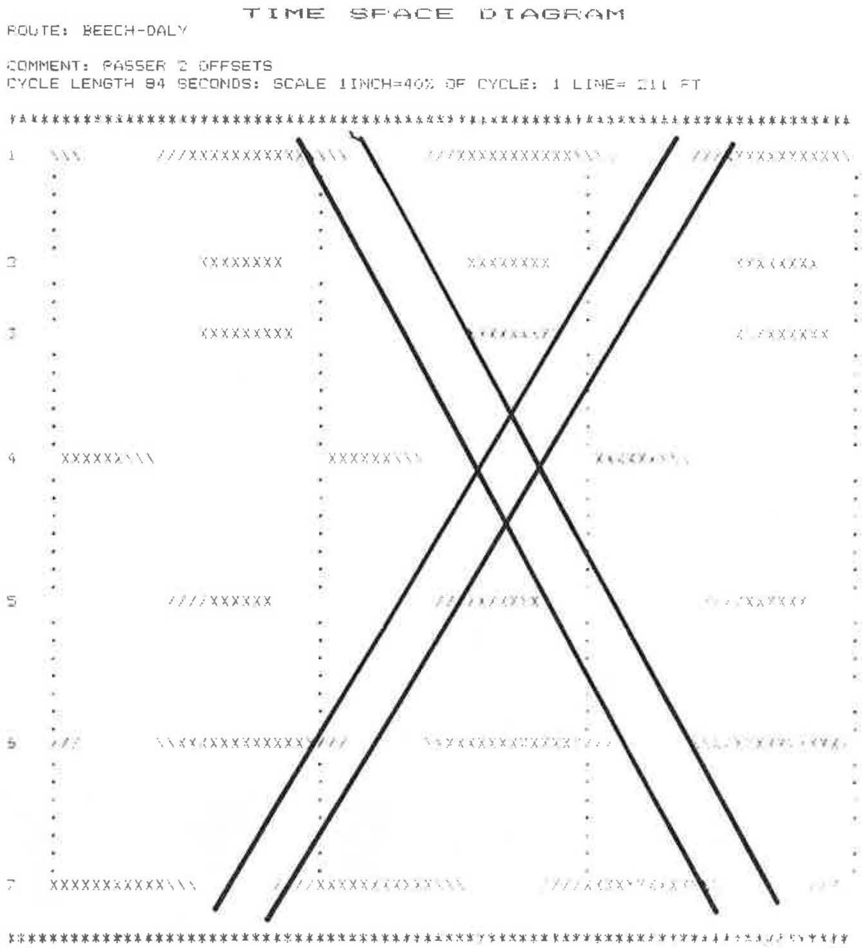


FIGURE 9 SPAN TSD of Beech-Daly system.

ample is given in this section by using the PPD concept to graphically illustrate the advantages of the system efficiency strategy.

The following example compares the TSD with the PPD and the TLD for a section of Beech-Daly Road in Detroit. The same design (PASSER II optimization) is depicted in each case. A constant speed of 45 mph is assumed throughout this section, which contains seven traffic signals.

The TSD is shown in Figure 9. This is a standard printed output from the SPAN program, auto-scaled to fit conveniently on one page. The progression bands have been added to this figure for emphasis.

The corresponding TLD is shown in Figure 10; this also is an output of the SPAN program. Again the leading and trailing edges of the progression bands have been added. Note that in this case the bands do not have the characteristic slope of the TSD because of the correction for travel time. This permits the entire route to be compressed into a much smaller space. The advantages of the compression are as follows.

1. Compatibility with the shape of the videoscreen on a microcomputer: The SPAN program displays the TLD on the screen and allows manipulation of offsets from the keyboard. This is a powerful editing feature for the design of simple arterial systems.

2. Assessment of the quality of progression: Progression throughout a portion of the system is easier to visualize on the TLD because all of the signals are immediately adjacent to each other. Critical signals that interrupt progression are also more apparent. Note, for example, how intersection 3 stands out as the critical signal for rightbound progression in Figure 10.

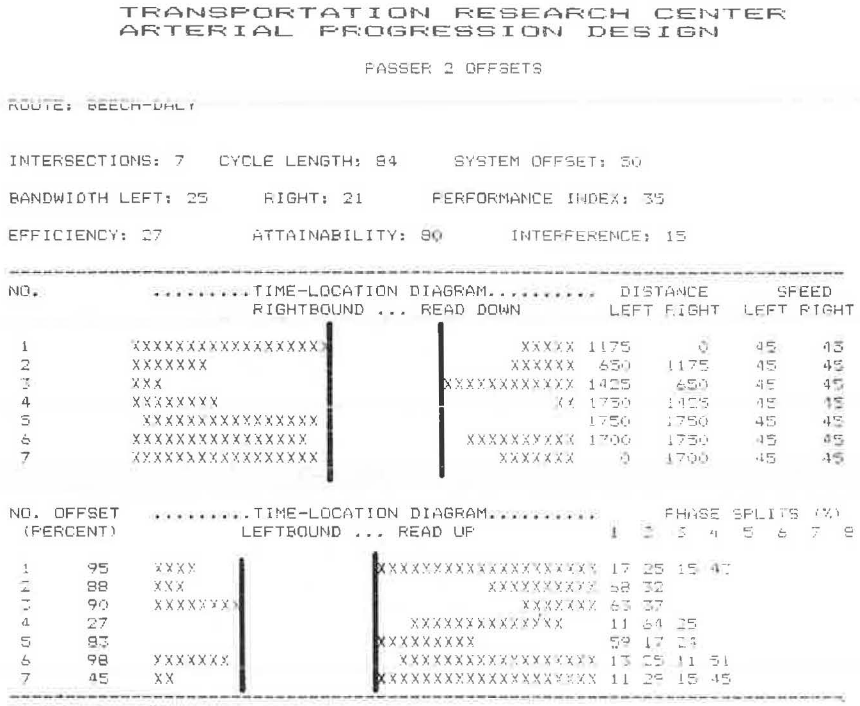
Some useful MOEs are also included in Figure 10. In addition to the commonly used measures of bandwidth, efficiency, and attainability, three other values are provided.

1. System offset: This is not really an MOE but simply an indication of the amount by which all offsets were shifted to center the progression bands on the page for easier interpretation.

2. Performance index: This measure indicates the total PROS, as defined earlier in this paper. It is expressed as a proportion of the cycle length. Its value is usually greater than the progression efficiency because of progression opportunities that occur throughout a portion of the system (e.g., between intersections 2 and 4, rightbound).

3. Interference: This measure indicates the proportion of time in which a vehicle released from one signal will be stopped at the next signal. It has at least an intuitive connection with safety and driver comfort. Interference is much more apparent on the TLD because of the adjusted alignment of the red intervals.

The TLD and TSD only show time relationships among the signals. As such, they are not concerned with the actual movement of traffic. As noted earlier, this is their main shortcoming. They reflect



```
              TRANSPORTATION RESEARCH CENTER
              ARTERIAL PROGRESSION DESIGN

                         PASSER 2 OFFSETS

ROUTE: BEECH-DALY

INTERSECTIONS: 7   CYCLE LENGTH: 84      SYSTEM OFFSET: 50

BANDWIDTH LEFT: 25      RIGHT: 21       PERFORMANCE INDEX: 35

EFFICIENCY: 27        ATTAINABILITY: 80       INTERFERENCE: 15

-----------------------------------------------------------------------
NO.            .........TIME-LOCATION DIAGRAM.........  DISTANCE     SPEED
                        RIGHTBOUND ... READ DOWN      LEFT RIGHT  LEFT RIGHT

 1          XXXXXXXXXXXXXXXXXX                  XXXXX 1175     0    45    45
 2          XXXXXXX                            XXXXXX  650  1175    45    45
 3          XXX                          XXXXXXXXXXXX 1425   650    45    45
 4          XXXXXXXX                               XX 1750  1425    45    45
 5           XXXXXXXXXXXXXXXX                         1750  1750    45    45
 6          XXXXXXXXXXXXXXXX                XXXXXXXXX 1700  1750    45    45
 7          XXXXXXXXXXXXXXXXX                 XXXXXXX    0  1700    45    45

NO. OFFSET     .........TIME-LOCATION DIAGRAM.........      PHASE SPLITS (%)
 (PERCENT)             LEFTBOUND ... READ UP             1  2  3  4  5  6  7  8

 1     95    XXXX          XXXXXXXXXXXXXXXXXXXX 17 25 15 43
 2     88    XXX                     XXXXXXXXXX 68 32
 3     90    XXXXXXXX                   XXXXXXX 63 37
 4     27                      XXXXXXXXXXXXXX   11 64 25
 5     93                  XXXXXXXXX            59 17 24
 6     98    XXXXXXX         XXXXXXXXXXXXXXXXXX 13 25 11 51
 7     45    XX            XXXXXXXXXXXXXXXXXXXX 11 29 15 45
-----------------------------------------------------------------------
```

FIGURE 10 SPAN TLD of Beech-Daly system.

what the motorist can expect to encounter only under extremely light traffic conditions. As traffic volumes increase, the actual conditions will depart substantially from the ideal picture presented by the TSD and the TLD. The PPD provides the solution to this problem.

The PPD for the Beech-Daly system is shown in Figure 11. Two points are apparent:

1. Considerable movement of traffic occurs outside of the progression bands (note that the bands are added to the drawing for purposes of comparison), and
2. Queues build up within the bands at several intersections; in other words, the progression bands travel smoothly through the system, but most of the vehicles must stop.

The PPD clearly shows how the traffic is affected by the signals. It also provides some insight into the rationale behind the signal timing design produced by the TRANSYT model. The TRANSYT view of the system operation is exactly what is shown on the PPD.

CONCLUSIONS

The recent massive increase in the use of microcomputers has provided the traffic engineer with greatly enhanced graphics capabilities. An excellent example is found in signal progression design. The time-space diagram, which has been used universally for the past 50 years, is primitive and inadequate for many purposes. The graphics techniques presented in this paper extend the concept of the time-space diagram. The techniques may be implemented easily and are powerful tools in the design and analysis of traffic control systems.

REFERENCES

1. PASSER II 80 User's Manual. Texas State Department of Highways and Public Transportation, Austin, Dec. 1982.

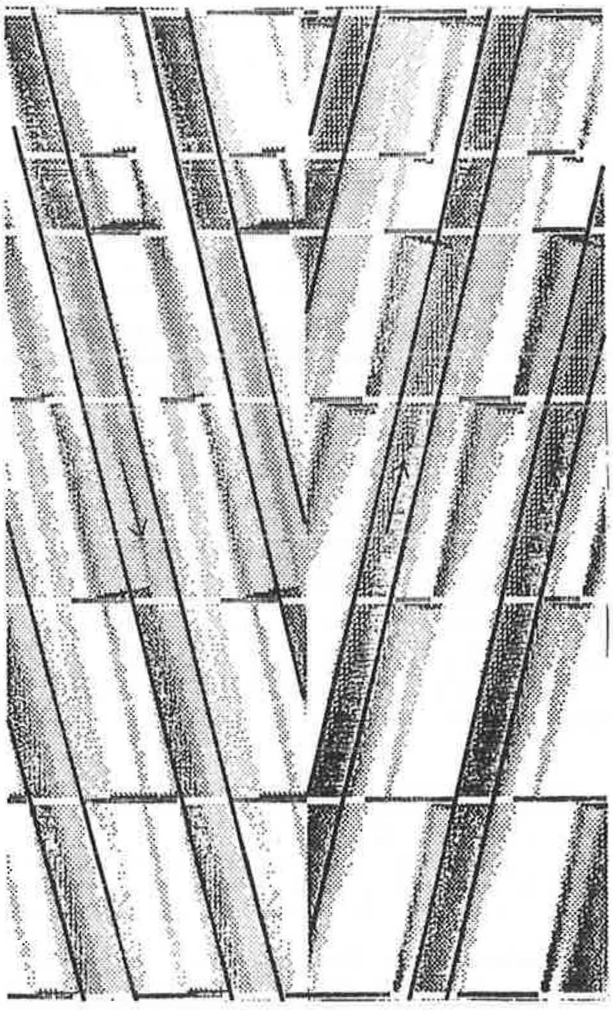


FIGURE 11 PPD of Beech-Daly system.

2. J.C.D. Little and M.D. Kelson. Optimal Signal Timing for Arterial Signal Systems. Operations Research Center, Massachusetts Institute of Technology, Cambridge, Dec. 1979.
3. C.E. Wallace et al. TRANSYT-7F User's Manual. Transportation Research Center, University of Florida, Gainesville, Feb. 1983.
4. E.B. Lieberman and J.L. Woo. SIGOP II: Program to Calculate Optimal Cycle-Based Traffic Signal Timing Patterns--Volume I: User's Manual. KLD Associates, Inc., Huntington Station, N.Y., Oct. 1978.
5. D.I. Robertson. TRANSYT: A Network Study Tool. Report LR 253. Road Research Laboratory, Crowthorne, Berkshire, England, 1969.
6. R.A. Vincent, A.I. Mitchell, and D.I. Robertson. User Guide to TRANSYT, Version 8. Report 888. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1980.
7. C.E. Wallace and K.G. Courage. Arterial Progression--New Design Approach. In Transportation Research Record 881, TRB, National Research Council, Washington, D.C., 1982, pp. 53-59.
8. C.E. Wallace. Development of a Forward Link Opportunities Model for Optimization of Traffic Signal Progression on Arterial Highways. Ph.D. dissertation. University of Florida, Gainesville, 1979.
9. K.G. Courage, C.E. Wallace, and D.P. Reaves. Arterial Analysis Package (AAP), User's Manual. Transportation Research Center, University of Florida, Gainesville, 1982.
10. K.G. Courage. Signal Progression Analysis (SPAN), McTrans Volume 1. Transportation Research Center, University of Florida, Gainesville, 1980.
11. Bandwidth Isn't the End (BITE), User's Manual. Microtrans Associates, Inc., 1983.
12. K.G. Courage. Computer Graphics: A New Look at Signal Progression. In Compendium of Technical Papers, 43rd Annual Meeting of ITE, Sept. 1973.

Publication of this paper sponsored by Committee on Traffic Signal Systems.

Analysis of Parking in Urban Centers: Equilibrium Assignment Approach

YEHUDA J. GUR and EDWARD A. BEIMBORN

ABSTRACT

Parking policies and supply play a major role in the management of transportation systems in dense urban areas. A method for representing and analyzing parking is described. Included in the procedure are calculations of parking impedance for each destination point in a study area and the determination level of use of each parking location in the area, including illegal parking. In the model the amount of time spent looking or waiting for a parking space is an increasing function of the utilization level of the parking area. With this relationship it is possible to describe and analyze the parking process in the framework of user-optimized equilibrium assignment. All of the major factors that affect parking behavior in urban areas are accounted for, including walk to destination, parking fees, parking regulations, intensity of enforcement, and supply-demand relationships. The model and its testing in a dense section of the city of Haifa, Israel, are described. In this test case parking behavior is examined as it varies with value of walk time, parking cost, parking fines, enforcement policies, and level of travel demand.

In densely developed sections of urban areas such as the central business district (CBD), parking constitutes a large part of the total travel impedance of travelers who use private automobiles. Parking management can be an effective tool for controlling the number and nature of automobile arrivals. Such control can be realized in a number of ways, from individual changes in modal split or trip scheduling to overall changes in the level of activity of an area. Possibly one of the most important questions in the management of transportation in urban centers is the determination of a level of parking supply that encourages arrival by public transportation, while at the same time prevents loss of activity because of parking shortages. Because of the fear of potential business loss through rigid parking control, managers are unwilling to experiment with changes in parking policy as an element in the management of transportation systems.

A model that analyzes parking in dense urban areas is described. The model is designed to serve as part of a modeling system for the analysis of the impact of integrated transportation system management (TSM) strategies in city centers. The parking model has also proved to be an effective independent tool for parking design, and it will be presented here as such.

The purpose of the model is to simulate parking choice and to provide the following information: