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Traffic Analysis Software Tools

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FOREWORD

This Transportation Research Circular is an overview of Traffic Analysis Software Tools. It was developed for the Committees on Traffic Signal Systems (A3A18) and Traffic Flow Theory and Characteristics (A3A11) of the Transportation Research Board. It is intended for use by state and local transportation agency personnel and consultants to understand the availability and applicability of traffic software analysis tools.

Administrators, engineers, and researchers are continually faced with traffic problems and situations that are often not easily solved by simple engineering analysis techniques. Models have been developed to facilitate such analyses, and many of these have been implemented in software. Often, managers are not familiar with the software tools available, and as a result, such tools are not always used for these analyses. This report of the Transportation Research Board describes the state of the art in traffic software tools, primarily for the benefit of managers and administrators.

TRB WEBSITE: nationalacademies.org/trb

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TRAFFIC ANALYSIS SOFTWARE TOOLS

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INTRODUCTION

Twenty years ago only a limited number of practitioners had access to the large-frame computers required to use computerized traffic modeling tools. Highway/transportation departments, large metropolitan areas, universities, and large companies were the fortunate few. Others had to use analytical, manual techniques, or pay a high price for commercial computer services.

Now, microcomputers are as commonly available as the electronic calculators of the 70s and, while more expensive than calculators, are easily within the economic reach of virtually every transportation professional in most locations throughout the world.

Developers of computerized traffic tools, such as the U.S. Department of Transportation and some state Departments of Highways and Transportation, universities and private organizations have promulgated a substantial suite of software tools for every phase of transportation planning and engineering in the past decades. The Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) have even set up microcomputer software distribution and support centers to help get the products to users.

Currently for example, the Center for Microcomputers in Transportation (Mc*Trans*), lists over 475 software tools in these functional areas:

- Construction management;
- Highway design, pavements, bridge design and hydraulics;
- Maintenance;
- Safety and accident records;
- Surveying;
- Traffic engineering;
- Transit; and
- Urban transportation planning.

The largest single group of software concerns traffic operations. Traffic operations software tools have a wide range of applications. Some of them provide an alternative to manual applications of widely used highway capacity analysis procedures. Others utilize simulation for evaluation of the impact of changing traffic patterns, geometric designs and control strategies. Also a number of tools have imbedded optimization capabilities to allow the development of the best control strategies.

Despite the abundance of traffic operations software, the lack of understanding of such software among the executive and management levels of the transportation engineering profession has inhibited software applications. Many public and private leaders in the profession do not know what software is available or about its capabilities. They mistrust computers in general and sometimes even fear software because of the "black box" syndrome. The latter is certainly a legitimate concern, but proper education in the first two areas, coupled with *competent and proper use of computer programs by practitioners,* can go a long way to allay the fear of the black box.

The first question is, perhaps, "Why use computerized traffic tools in the first place?" Computerized traffic tools can be used to substantially increase the number of alternative problem solutions an engineer, planner or analyst can consider. Indeed, using computerized tools lets one examine potential solutions that are impossible to consider with manual, analytical methods. Productivity is increased by an order of magnitude over traditional non-computerized techniques.

Using simulation tools lets us try out proposed designs and transportation improvements in the safety of the office without subjecting the public to potential hazards, and at considerably less cost than field trials. Optimization tools give the designer the opportunity to consider many options in a matter of minutes. There are many reasons to use such tools, but these are the main ones.

The abundance of programs available today also creates some practical questions for users and managers. "What program should I buy? Is there one program that can do it all?" Obviously, one must determine the objective of a specific application before choosing the "best" program. Unfortunately, this is not always the case, because many users and agencies usually do not know enough about the programs. It is not unusual, therefore, to purchase a number of programs and eventually only use one or two of them.

Recognizing the need to better educate and inform both leaders and practitioners about software, several agencies have set about a multi-pronged education program. In 1993 the FHWA published the second edition of a "Traffic Models Overview Handbook (1, 2)." This very detailed handbook is aimed at practitioners to give them an in-depth view of the programs' capabilities, so they can thoroughly evaluate the potential applications. This handbook may, however, be too detailed for most executives and managers, plus it was not very widely distributed.

A compact disc (CD), "Advanced Traffic Analysis," was developed for FHWA that offers those with CD-ROM drives on their computers an excellent preview of most of today's publicly available traffic operations software. While the multi-media presentation is unsurpassed as a presentation medium, its exposure to executives and managers might be limited.

To fill this vital gap in getting information on computer tools (primarily) to the leadership of agencies and companies, the Transportation Research Board (TRB) undertook this effort to develop an "executive primer" on traffic operations tools (3). The TRB Committees on Traffic Signal Systems and Traffic Flow Theory formed a joint task force in January 1995 to develop a circular on this topic (4).

PURPOSE

The primary purpose of this circular is to present a concise, yet comprehensive introduction to the world of traffic operations analysis and optimization tools (5). Specifically, it identifies and promotes traffic model applications for signalized and unsignalized intersections, arterial highways, networks, freeways, and freeway/arterial corridors.

The objectives are to

- Identify the most useful, and most used, publicly as well as privately developed computerized packages for the profession, and
- Introduce the basic functions and capabilities of the software products.

The primary audience of the primer is the upper organizational echelon of agencies, although it should be of equal interest to practitioners as a convenient prelude to the handbook and CD-ROM products.

SCOPE

Traffic congestion and mitigation, advanced traffic management strategies, non-construction-based improvements, and signal timing and re-timing, are among the areas in which traffic operations tools can be used effectively to help engineers make sound planning, design, and operating decisions. This circular covers programs for traffic operations that provide for simulation, capacity analysis, traffic signal timing analysis and optimization, and freeway and corridor operations. Software used purely for data-collection is not considered for inclusion.

As noted above, both publicly and privately developed software products are included in the circular. Selection was made by the task force, based on two basic methods (The task force comprises experts in this field and most of the selected packages were well known to them.):

- A general "call for offers" was distributed in the March 1995 Mc*Trans* newsletter for others to request inclusion of their products (6).
- Selected software has to meet these criteria, and
  - If developed, the software must have had a proven "track record," including documented users or an acceptable publication record.
  - If under development, the value to the profession needs to be self-evident.

ORGANIZATION

This circular covers five major applications areas, as follows: 1) isolated intersections, 2) arterial highways, 3) networks, 4) freeways and freeway corridors, and 5) special analyses. Each area and its associated tools are discussed in the following sections.

It might be obvious that some tools listed in one application area can have multiple applications. In such a case the tool is listed in accordance with its primary application.

ISOLATED INTERSECTION ANALYSIS AND SIGNAL TIMING TOOLS

Traffic analysis and optimization tools for isolated intersections have more than tripled in the past five years. One reason is the promulgation of the Highway Capacity Manual (HCM), most recently updated in 1997 (TRB, 1997). The Highway Capacity Software

(HCS) (Sampson et al., 1997), was developed as a full and faithful implementation of the HCM, at least for all the commonly used chapters/facilities, but is limited to the HCM procedures. Developers have sensed the need for other functionality, such as additional performance measures, unusual geometry and, of course, design features. Recent additions to the suite of intersection analysis tools have tended to combine this expanded functionality with either the HCM procedures by imbedding them directly or by linking to the HCS.

Some tools naturally perform still other functions altogether, but all have a role in the intersection design and analysis process (7). Typical examples of commonly used performance measures are delay, queues, number of stops, fuel consumption, and vehicle exhaust emissions.

Most importantly, some of the advanced tools can optimize phase sequences, cycle lengths and signal timing settings for actuated controllers. Some packages even provide users with animation and visualization tools.

Tables 1 and 2 feature several major intersection-based programs. These programs include EVIPAS, HCM/CINEMA, HCS, SIDRA, SIGNAL97, SOAP, and Texas. Table 1 presents a summary of the tools' characteristics, such as applications and results. Table 2 lists the tools' data input and computer system requirements. Each of these programs is discussed below.

Highway Capacity Software

The most widely used computerized highway capacity method for signalized intersections is the Highway Capacity Software (HCS) (8). It is a user-friendly procedure for estimating intersection capacity and level of service (LOS). As noted earlier, the HCS is a faithful implementation of the HCM. It performs the procedures in the manual, and no more.

The HCS allows the user to enter intersection configuration data, traffic flows, and signal phasing and timing data to compute stopped delay, volume-to-capacity ratio and LOS. The HCS does not perform timing design. The HCS application is limited to four-leg intersections, multiple turning lanes and pre-timed and actuated signal control, to the extent covered in the HCM.

A Windows-based version of the HCS is replacing the DOS version in early fall 1998. This version of HCS is fully compatible with the 1997 update to the HCM.

HCM/CINEMA

HCM/CINEMA combines the HCM Chapter 9 procedure for analyzing isolated signalized intersection level of service with a microscopic simulation tool (9). In addition to the basic HCM procedure, HCM/CINEMA optimizes the phase splits when used for design applications. The program allows the user to view intersection graphics during data entry and, most importantly, to view a microscopic simulation and dynamic animation of the results, using the simulation outputs of the NETSIM program (see section on CORSIM/NETSIM).

The NETSIM module used to create the simulation and animation is included with HCM/CINEMA; thus it needs not be acquired separately. HCM/CINEMA can also link to word-processing and desk-top publishing software to enhance the appearance and clarity of reports.

The animation feature of HCM/CINEMA is very effective as a PR tool, especially for small meetings, as well as for evaluating timing plans, geometric improvements and determining operational problems, such as queuing and overflows. HCM/CINEMA also offers measures of effectiveness (MOEs) such as delay, level of service, average speed, spillback in the worst lane, fuel consumption, emissions, speeds and queues. Passive and dynamic graphics screens can be printed at any time during a session of HCM/CINEMA. Animated screens can be zoomed and panned to view traffic movements and queuing on any section of the simulation approaches. The limits of HCM/CINEMA include four approaches, six lanes on each approach, two left-turn lanes, two right-turn lanes, six outbound lanes, 1300 m (4000 ft) for approach length, up to 330 m (1000 ft) for pocket lanes, up to 5 m (15 ft) lane width and up to 9999 vehicles per hour per movement. Other defined parameters include heavy vehicles, pedestrians, parking maneuvers, transit, and signal phasing. HCM/CINEMA is compatible with the 1994 update to the HCM.

SOAP

Signal Operations Analysis Package (SOAP) can be used to determine signal timing plans for pre-timed controllers and limited capabilities for actuated controllers (10). Although SOAP is still used by several agencies,it has been largely overshadowed by more advanced and broader programs. Its main appeal is its inclusion in the Wizard of Helpful Intersection Control Hints (WHICH) package, so it serves many users as a timing plan optimizer for use in conjunction with WHICH-supported tools (11).

The original version (still separately available) can perform multi-period analysis, but the WHICH version is a single-period tool, since all other programs in the WHICH suite are limited to single periods. The program optimizes cycle lengths and splits based on delay and stops.

SIGNAL97

SIGNAL97 can be used to perform capacity analysis, signal timing optimization and design of intersection geometry and control. SIGNAL97 is based on the 1997 update of the HCM. SIGNAL97 can analyze existing traffic conditions and timing as well as generate optimum signal timing and phasing patterns. The optimizer seeks to establish the best attainable LOS for critical movements within a specified range of cycle lengths.

The major benefit of the program is the flexibility it offers users to develop individual intersection control strategies spanning a variety of possible signal timing solutions. For example, SIGNAL97 can be used to find the best cycle length for a given LOS, to find the best phase sequence and optimal splits for a given cycle and a given LOS, to optimize the cycle length over a range of LOSs, and to analyze protected and permitted left turns. It can provide a full summary report similar to the HCS but with more MOEs, such as maximum queues, fuel consumption, emissions, number of vehicles stopped, and average and total delay. SIGNAL97 also provides a schematic of the best phase sequence.

Another unique feature of SIGNAL97 is its planning application. Even with unknown signal phasing and timing data, the program can be used to optimize signal phasing and timing based on proposed geometry and forecast volumes. In addition, the input and output data for SIGNAL97 are fully integratable with any of the TEAPAC program family of tools (12, page 24). It is available for DOS and Windows.

SIDRA

Signalised and Unsignalised Intersection Design and Research Aid (SIDRA) is an intersection-based program developed by ARRB Transport Research, Ltd., in Australia as an aid for capacity, timing and performance analysis of isolated intersections (13). SIDRA is a very powerful analytical program for signalized intersections; roundabouts; and yield-, two-way stop-, or all-way stop-controlled intersections, with up to eight approaches. Besides optimizing phase sequences, splits, and cycle lengths, SIDRA has a wealth of graphic displays of intersection geometry, including the number of lanes, turning lanes, and channelization.

An option to implement the U.S. HCM method is include d in SIDRA to help the analysis and investigation of the differences between the SIDRA and HCM methods. SIDRA can be used to perform lane-by-lane analysis, lane flow calculations, shared lanes and lane blockage, right turn on red, capacities of short lanes, performance measures, variable cycle lengths, variable flow scale, and modeling of unequal lane utilization. The variable cycle length profiles allows agencies to determine the best cycle length and phase sequence based on user-determined criteria for signal optimization. Such functions include minimizing stops and delay, queues, vehicle emissions, fuel consumption, or operating cost. The variable flow scale profiles can be used to investigate future growth scenarios. SIDRA has the capability to model upstream and downstream short lanes, slip lanes, shared lanes, and opposed turns with multiple green periods.

SIDRA is perhaps the richest MOE-based intersection program. It offers MOEs such as total and average delay, v/c ratios, queues, stops, speeds, fuel consumption, emissions, and operating costs. SIDRA is the only program that calculates capacity-based MOEs on a lane-by-lane basis for all approaches, in addition to the total intersection MOEs. SIDRA is designed for single time periods, random arrival patterns (but with provision for platooned arrivals generated by coordinated signals), and pre-timed or actuated signals.

SIDRA is also one of three tools that are currently used in the U.S. for capacity analysis for roundabout intersections (the other two programs being ARCADY and Rodel, both British programs). For roundabout intersections, SIDRA can analyze intersections with up to eight approaches and also has provisions to assume either random or platooned arrivals (bunched vehicles) to analyze the effect of progression from nearby signalized intersections.

EVIPAS

All of the above isolated intersection programs offer limited applications to actuated-controlled intersections. Enhanced Value Iteration Process for Actuated Signals (EVIPAS) is an optimization and simulation tool (14). EVIPAS is capable of analyzing, and developing the optimal settings for, a wide variety of intersection geometric configurations, detector layouts, and actuated dual-ring controller phasing sequences. The user can select any of several MOEs as the basis for optimizing signal parameters for pretimed, semi-actuated, and fully-actuated controllers, including volume-density control. EVIPAS also accounts for actuated pedestrian movements. EVIPAS' input data include intersection and approach geometric configurations, traffic flows, signal phasing, minimum signal timing periods, and optimization parameters.

The tool's outputs include signal parameter settings, percent stops, operating costs, average stopped delay, and total vehicles discharged. The signal timing output consists of signal-phase variables such as minimum green, vehicle extension, added initial, maximum initial, time before reduction, time to reduce, and minimum gap. EVIPAS can model only a single left-turn lane, up to three thru lanes, a single right-turn lane, and intersections with up to five approaches. Two types of detectors are supported: stopline presence detectors and passage detectors. Only one presence detector is allowed per lane; a total of three detectors is allowed for each approach. EVIPAS does not optimize phase sequences has no graphics displays.

Texas

While all of the above programs provide users with analytical means to analyze and evaluate traffic conditions and intersection control strategies, only two programs are capable of microscopic simulation and animation of intersection traffic and roadway conditions: CORSIM and Texas (15). (See section on CORSIM/NETSIM)

Microscopic simulation is useful because it provides very detailed simulation of each individual vehicle within an intersection or a network of streets.

Texas is used to evaluate the operational effects of various traffic demands, types of traffic control, and/or geometric configurations at individual, isolated intersections. It may be applied in evaluating existing or proposed intersection designs and for assessing the effects of changes in roadway geometry, driver and vehicle characteristics, flow conditions, intersection control, lane control, and signal timing plans upon traffic operations. It also has the capability to analyze signalized diamond interchanges.

A major strength of Texas is its ability to model real-world traffic applications including pretimed, semi-actuated, fully-actuated controllers, and double and triple left-turn lanes. Besides CORSIM, Texas is the only microscopic intersection-based program that can simulate actuated controllers and lane-by-lane performance. Texas operates in a user-friendly, interactive environment. Special features include an animated graphics display that shows color-coded vehicles moving through the intersection.

ARTERIAL ANALYSIS AND SIGNAL TIMING TOOLS

Arterial tools are grouped into two categories: operational analyses and signal timing designs. The analysis methods of the operational tools for uninterrupted and interrupted flow are covered explicitly in Chapters 7 and 11 of the HCM, respectively. Optimization methods for arteries are covered in two widely accepted tools, namely PASSER II and PASSER III (16, 17).

Since its development in 1986, the computerized tool (HCS-Arterials) for Chapter 11 of the HCM has been extensively used by traffic engineers and transportation planners. Generally, the objective of an operational analysis is to determine the total delay and level of service for an artery. With design, however, the optimization objective function is typically to maximize the sum of green bands on the artery by selecting the best cycle, splits and offsets solutions. Such solutions are usually achieved with PASSER II for normal arteries. Special applications for optimization of signal timing at frontage road arteries and diamond interchanges also are achieved by PASSER III. The characteristics, data requirements, performance measures and computer system requirements for these tools are summarized in Tables 3 and 4.

HCS-Multilane

The HCS-Multilane method is used for analyzing uninterrupted flow on rural and suburban artery highways, based on Chapter 7 of the HCM.

Data required for multilane analysis include traffic and roadway conditions, such as hourly traffic volumes and peak hour factors, terrain type, number of lanes, grade, vehicle classification and composition, free-flow speed, median type, lateral clearance and number of access points per mile. The results of the analysis include service flow rate, free-flow speed, average passenger-car speed, density and LOS. The LOS is defined by the density of traffic.

HCS-Arterials

HCS-Arterials implements the procedures in Chapter 11 of the HCM. HCS-Arterials allows users to perform both operational and planning analyses. For example, in the case of an operational problem, the analysis determines the arterial LOS by investigating the effects of signal spacing, arterial classification, and traffic flow. The analysis method uses the HCM signalized intersection procedure for the lane groups containing thru traffic.

Basic data required for the operational analysis include separation distance and free-flow speed between intersections; artery class for principal and minor arteries, such as urban, intermediate, and suburban (defined in Table 11-2 of the HCM); intersection cycle length; phase sequence; signal timing; and arrival type.

HCS-Arterials results are presented on a section-by-section basis and include intersection total delay, running time, arterial speed, and arterial level of service. The LOS is based on the average travel speed and the arterial classification.

The HCS-Arterials planning method determines the LOS for a given average annual daily traffic (AADT) value and can also suggest a maximum AADT for a given LOS. The planning method uses the same methodology as the operational analysis, but the arterial LOS is determined using default parameter values for signalized intersections.

Data required for the planning analysis include AADT, desired LOS, design-hour factor (K), directional distribution factor, peak hour factor, adjusted saturation flow rate, percent turns from exclusive lanes, number of thru lanes, artery classification, median condition, free-flow speed, section length, number of signalized intersections in the analysis, arrival type for traffic, and signal-related data similar to the operations analysis. Results include projected two-way hourly volumes, running time, average travel speed, and arterial LOS.

PASSER II

PASSER II (Progression Analysis and Signal System Evaluation Routine, Tool II—arteries) was originally developed in 1974 by the Texas Transportation Institute (TTI). PASSER II is an arterial-based bandwidth optimizer, which determines phase sequences, cycle length, and offsets for a maximum of 20 intersections in a single run. Splits are determined using an analytical (Webster's) method, but are fine-tuned to improve progression (18). PASSER II assumes equivalent pre-timed control, but it does represent dual-ring phasing.

PASSER II requires traffic flow and geometric data, such as design hour turning volumes, saturation flow rates, minimum phase lengths, distances between intersections, cruise speeds, and allowable phase sequencing at each intersection.

The PASSER II timing outputs include design phase sequences, cycle length, splits, and offsets, and includes a time-space diagram. Performance measures include volume-to-capacity ratio, average delay, total delay, fuel consumption, number of stops, queue length, bandwidth efficiency, and level of service.

In addition to the time-space diagram, PASSER II has a dynamic progression simulator, which lets the user visualize the movement of vehicles along the artery using the design timing plan.

PASSER III

PASSER III, also developed by TTI, analyzes signalized diamond interchanges. The program can evaluate existing conditions and optimize signal timing that minimizes average delay. It may also calculate signal timing plans for interconnecting a series of interchanges along one-way frontage roads, similar to PASSER II.

PASSER III is capable of analyzing various multi-phase treatments, either with or without left-turn lanes, including permitted, protected, and permitted-plus-protected left-turn treatments. Common types of diamond interchanges analyzed by the program include half diamond, full diamond, full diamond with frontage roads, and split diamond.

PASSER III requires the same basic data as PASSER II, but the volume data must be specific as to interchange entry-exit points and additional data are needed on internal storage capacities.

PASSER III results are similar to that of PASSER II in terms of MOEs and signal timing settings, but no animated display is available.

NETWORK SIGNAL ANALYSIS, TIMING AND SIMULATION TOOLS

In the 1980s network signal design was dominated by TRANSYT-7F for optimizing delay, stops, and fuel consumption (19). A second tool, MAXBAND, was written for optimizing green bands on arteries in networks; however, it was not widely used because of extreme run times and being limited to mainframe users. It is now available for PC applications and runs more efficiently, but it is not widely available or used.

In recent years, however, two other programs have emerged: SYNCHRO and PASSER IV (20, 21). Although SYNCHRO duplicates much of the TRANSYT-7F functionality and capability, it offers broader applications and utilities. It has a better user interface; enhanced post-processing (including an interactive platoon dispersion diagram) and serves as a preprocessor for TRANSYT-7F, PASSER II, and CORSIM.

PASSER IV is a derivative of MAXBAND, retaining its objective function of optimizing green bands for arteries in the network. Tables 5 and 6 provide the details of the programs in this section.

TRANSYT-7F

TRANSYT-7F (**TRA**ffic **N**etwork **S**tud**Y** **T**ool, version 7, Federal) is designed to optimize traffic signal systems for arteries and networks. The program accepts user inputs on signal timing and phase sequences, geometric conditions, operational parameters, and traffic volumes.

TRANSYT-7F is applied at the arterial or network level, where a consistent set of traffic conditions is apparent and the traffic signal system hardware can be integrated and coordinated with respect to a fixed cycle length and coordinated offsets. Although TRANSYT-7F can emulate actuated controllers, its application is limited.

TRANSYT-7F optimizes signal timing by performing a macroscopic simulation of traffic flow within small time increments while signal timing parameters are varied. Design includes cycle length, offsets, and splits based on optimizing such objective functions as increasing progression opportunities; reducing delay, stops, and fuel consumption; reducing total operating cost; or a combination of these.

For simulation, the program accepts the inputs as fixed variables and reports the performance measures in terms of stops, delay, fuel consumption, and queuing. When optimization is performed the user can either fix or select the best cycle length with the least delay and stops. Detailed optimization of offsets and splits can be performed for either a user-specified cycle length or the "best" cycle length found by the program. TRANSYT-7F's performance measures include delay, stops, queue length, travel time, level of service, volume-to-capacity ratio, speed, total travel, fuel consumption, and operating cost. When optimizing, TRANSYT-7F minimizes or maximizes an objective function, called the Performance Index (PI). The PI may be a combination of delay and stops; fuel consumption; and/or optionally selected excessive maximum back of queue, excess operating costs, or progression opportunities.

TRANSYT-7F has its own pre- and post-processors; namely, a simple data editor (T7FDIM) and the Platoon Progression Diagram (PPD). The T7FDIM provides the ability to edit all record types of an input file. T7FDIM, however, requires that the user has intimate knowledge of the TRANSYT-7F data record types, ordering, and contents.

The PPD presents a "contour" of flow versus time and distance along an artery. Queue build-up, dispersion and arrival of platoons are clearly shown for a visual insight on the flow patterns normally occurring along the artery.

Other simplified and popular pre- and post-processors for TRANSYT-7F network applications include programs such as EZ-TRANSYT PLUS, PRETRANSYT, Quick-7F and SYNCHRO (22). (See section on SYNCHRO below.)

Unique features of TRANSYT-7F include the program's ability to analyze double cycling, multiple greens, overlaps, right-turn-on-red, unsignalized intersections, bus and carpool lanes, "bottlenecks," shared lanes, mid-block entry flows, protected and/or permitted left turns, user-specified bandwidth constraints, and desired degree of saturation for movements with actuated control. Other applications of the tool include evaluation and simulation of "grouped intersections" (such as diamond intersections and closely-spaced intersections operating from one controller) and sign-controlled intersections.

The latest release (Release 8, issued in 1998) includes a number of enhancements: explicit handling of saturated conditions, including the effects of queue spillover and intersection blocking; multi-period analysis; random stops; LOS; simulation of different cycles among intersections; and optimization strategies for saturated conditions.

TRANSYT-7F is also available in both DOS and Windows 95/NT versions.

SYNCHRO

SYNCHRO is a macroscopic traffic signal timing tool that can be used to optimize signal timing parameters for isolated intersections, generate coordinated traffic signal timing plans for arteries and networks, and also develop time-space and platoon dispersion diagrams for interactive fine-tuning. SYNCHRO can analyze fully actuated coordinated signal systems by mimicking the operation of a NEMA controller, including permissive periods and forceoff points. SYNCHRO runs under Windows 95/NT and OS/2. Using a mouse, the user can draw either individual intersections or a network of intersecting arteries, and also can import .DXF map files of individual intersections or city maps. The program has no limitations on the number of links and nodes. It can analyze multi-legged signalized intersections with up to six approaches per intersection. SYNCHRO does not, however, analyze sign-controlled intersections.

SYNCHRO is designed to optimize cycle lengths, splits, offsets, and phase orders. The program also optimizes multiple cycle lengths and performs coordination analysis. When performing coordination analysis, SYNCHRO determines which intersections should be coordinated and those that should run free. The decision process is based on an analysis of each pair of adjacent intersections to determine the "coordinability factor" for the links between them.

SYNCHRO calculates intersection and approach delays either based on Chapter 9 of the HCM or a new internal method. The major difference between the HCM method and the SYNCHRO method is treatment of actuated controllers. The HCM procedures for calculating delays and LOS are embedded in SYNCHRO; thus, the user does not need to acquire HCM software.

SYNCHRO is useful for agencies that want to operate groups of arteries on different cycle lengths. Using SYNCHRO the user can optimize the entire network or groups of arteries and intersections in a single run and determine the control boundaries of the different arterial groups, based on the program's selection of the cycle lengths.

SYNCHRO requires mostly the same traffic flow and geometric data as TRANSYT-7F. The program can be used to evaluate existing traffic signal timing or to optimize the settings for individual intersections, arteries, or a network. The program performance measures include average approach delay, intersection delay, volume-to-capacity ratio, intersection level of service, 50- and 95-percentile queue lengths, total stops, travel time, emissions, and fuel consumption. Further, SYNCHRO has a generous listing of user-specified reports, including capacity analysis, LOS, delay, stops, fuel consumption, blocking analysis, and signal timing settings.

SYNCHRO has unique visual displays, including an interactive platoon dispersion diagram. The user can change the offsets and splits with a mouse, then observe the impacts on delay, stops, and LOS for the individual intersections, as well as the entire network.

Another significant strength of SYNCHRO is its ability to create data input streams for PASSER II, TRANSYT-7F, and CORSIM. Once the user has entered the data to run SYNCHRO successfully, it is possible to run any one of these programs without using any of their preprocessors (these programs must be acquired separately). Following a successful PASSER II or TRANSYT-7F run, the user has an option to use the results as inputs back into SYNCHRO, and perform further evaluations.

PASSER IV

Using hourly traffic volumes, user-defined saturation flow rates and optional minimum green times, PASSER IV can optimize the progression bands for main arteries as well as coordinated crossing arteries by computing the optimum cycle length, splits, phase sequences and subsequently adjusting the offsets for a maximum of 20 arteries and 35 intersections.

PASSER IV is derived from MAXBAND and has its own user interface and can print multiple signal timing reports and generate input data files for TRANSYT-7F.

The user interface for PASSER IV is very friendly. Its features include file management functions, context-sensitive help, a powerful output view/print capability, ability to display a network map and three data entry/edit capabilities. The basic data structure consists of a set of fully labeled screens arranged in hierarchical order. Data can be entered using the hierarchical data entry process, by directly working with the input data file using a built-in text editor, or by choosing entities from the network map display. The user interface also allows the user to run TRANSYT-7F for performing bandwidth-constrained disutility optimization. The inputs include link lengths, saturation flow rates, traffic volumes, average travel speeds, minimum green splits and the cycle length range.

CORSIM/NETSIM

Simulation tools are ideal tools for public presentations, evaluation of before and after studies, and routine planning and operations analysis. Simulation packages can offer the user a valuable tool to observe animated traffic conditions, and evaluate alternative scenarios for roadway and signal system improvements in urban areas.

Two earlier simulation tools (NETSIM for surface street networks and FRESIM for freeways) were recently combined into one tool, CORSIM. Some applications still use the independent NETSIM, but FRESIM has been totally integrated (see CORSIM/FRESIM section).

The NETSIM component of CORSIM is a program designed to simulate traffic operations for isolated intersections, arteries, and/or networks. Specific traffic applications include evaluation of capacity improvements, before-and-after improvement conditions, priority bus lanes, work-zone lane closures, draw-bridge closures, light-rail preemption, two-way stop-controlled intersections, and many other traffic conditions. The program supports fixed-time and actuated-controlled intersections. CORSIM is one of few programs described in this circular that supports actuated control in its true sense and emulates the functions of NEMA and Type 170 controller units.

The NETSIM component of CORSIM is limited to a maximum of 250 nodes, 500 links, 100 actuated controllers, 99 bus stops, and seven lanes per approach (with no more than two left and two right turn lanes per approach). NETSIM can handle approximately 60 intersections, with four-lane approaches. The maximum number of vehicles that may be accommodated is 10,000. CORSIM can model a maximum of five approaches per intersection. The “size” limits for FRESIM applications are higher.

CORSIM is a time-based microscopic tool with stochastic (random) simulation of individual vehicles in traffic-controlled urban networks and freeways. The CORSIM traffic flow logic performs a full range of controls on vehicles traveling within specific lanes and responding to any number of control devices including fixed time and actuated traffic signals, related surveillance systems, yield and stop signs, and ramp transitions. Vehicle flow is guided by car-following rules, lane-changing logic, and other driver decision-making processes.

CORSIM has a wealth of MOEs, including delays, queue length, queue time, stops, stop time, travel time, speeds, fuel consumption, emissions, and other congestion-based measures. These MOEs are calculated by movement and on a lane-by-lane basis for all intersection approaches.

Support programs for CORSIM include TSIS, the Traffic Software Integrated System, and TRAFVU. TSIS is a Windows-based platform that provides menu-driven access to CORSIM and others. TRAFVU is an interactive display post-processor.

CORFLO

CORFLO is an integrated set of five macroscopic tools: FREFLO, NETFLO 1 and 2, TRAFFIC and Capacity. NETFLO 1 and 2 provide a semi-detailed simulation of urban signalized street networks and, therefore, they are relevant to this section.

NETFLO 1

NETFLO 1 is comparable to NETSIM but it is an event-based simulation of traffic operations, rather than a time-based simulation (23). The major difference between NETSIM and NETFLO 1 is the level of detail of the individual vehicle movements. NETSIM moves each vehicle on a second-by-second basis according to a car following logic. NETFLO 1 is a simplified treatment of individual vehicles in the traffic stream that describes the traffic movement at a lower level of detail than NETSIM. NETFLO 1 moves each vehicle intermittently, that is whenever an event occurs, and moves that vehicle as far downstream as possible in a single jump. No car following logic is employed in NETFLO 1; therefore, NETFLO 1 does not generate detailed vehicle trajectories. Each vehicle in the network is treated as an identifiable entity. Its lateral and longitudinal position on a network link and its relationship to other vehicles are determined by the model's logic.

NETFLO 1 produces about the same MOE outputs as NETSIM, but requires less computer resources and execution time (but naturally, sacrificing "accuracy"). NETFLO 1 can simulate fixed-time, and emulates stop, yield control, and single-ring actuated control, but does not model dual-ring control.

NETFLO 2

NETFLO 2 produces results similar to NETFLO 1 and NETSIM. NETFLO 2 was adapted from the TRANSYT flow model. Inputs were simplified and the ability to handle time-varying traffic flows and multiple cycle lengths was added to overcome the deficiencies of constant traffic volumes and one uniform cycle length for traffic signals in TRANSYT. The traffic stream is described in terms of a set of link-specific statistical flow histograms. These histograms describe the platoon structure of the traffic stream on each network link. NETFLO 2 can only simulate fixed-time signal control, and stop and yield controls.

NETFLO 1 and 2 handle up to 700 links and 500 nodes, and 1500 links and 500 nodes, respectively. GCOR, the CORFLO interactive display post-processor, provides static and animated displays and traffic assignment capabilities to NETFLO 1 and 2.

The comparison of the major features of CORSIM and CORFLO's NETFLO 1 and 2 is given in Table 7.

FREEWAY/CORRIDOR ANALYSIS AND RAMP METERING DESIGN TOOLS

Freeway and corridor tools deal primarily with evaluation, simulation, and optimization of traffic operations on or at mainline sections, ramps, and High Occupancy Vehicle (HOV) lanes. The HCM, for example, has the most popular and widely accepted method for evaluating capacity and Level of Service for mainlines, weaving sections, and ramp junctions. The HCM method, however, performs neither optimization nor simulation for any of the freeway elements. In addition, it can't analyze the operation of integrated freeway sections of ramps and weaving. These functions are performed with tools such as INTEGRATION, CORFLO/FREFLO, FREQ and CORSIM (24-26). Each of these tools is discussed below and their features are summarized in Tables 8 and 9.

HCS

The Highway Capacity Software implements basic freeway sections in Chapter 3 of the HCM. HCS-Weave and HCS-Ramps incorporate the procedures defined in Chapters 3, 4, and 5 of the HCM for basic freeway sections, weaving areas, and ramps and ramp junctions, respectively. The basic freeway section module includes operational, design, and planning analyses. The operational analysis determines the level of service based on free-flow speed; existing traffic volumes; and roadway geometry, including number and width of lanes, grades, and lateral obstructions. The level of service determination is based on the computed conditions (maximum service flow rate and speed) for an equivalent ideal traffic stream. The design analysis of basic freeway sections is aimed at determining the number of freeway lanes to maintain a desirable level of service for a projected traffic volume. The planning analysis can be performed using either the design or the operational analysis methodology. Generally, the user supplies information on average annual daily traffic volumes or design hourly volumes.

Data input requirements for the basic freeway analysis include number and width of lanes, free flow speed, terrain, grades, lateral obstructions, vehicle mix, and traffic volumes.

Data input requirements for weaving analysis include non-weaving freeway and weaving traffic volumes, weaving type, number and width of lanes, terrain, lateral obstructions, and the driver population type, such as weekday commuters, as opposed to recreational travel. Outputs include weaving and non-weaving speeds and level of service. The level of service criteria are based on the derived speeds.

Ramp analysis deals with freeway on and off ramps. Data input requirements for ramp analysis include freeway and traffic volumes, length of acceleration or deceleration lanes, number and widths of lanes, terrain and free flow speeds of both the freeway as well as the ramp. Outputs include maximum density and expected average speed of vehicles in the ramp influenced areas and level of service. The level of service for ramps and ramp junctions is determined based on the computed maximum density in the merge influence area of the freeway.

INTEGRATION

INTEGRATION is a microscopic tool originally developed in 1984. The tool simulates the interaction of freeways and surface streets, traffic assignment, static and dynamic controls, and routings, in an integrated fashion. INTEGRATION represents the movement of individual vehicles in a time-stepping fashion, based on user specified speed-flow relationships for each link and dynamically considers multi-path vehicle routes in response to any traffic congestion that may develop during the course of a simulation run. This is one of the only tools currently in use that has some "intelligent vehicle" capabilities. INTEGRATION has the capability to evaluate weaving sections and arrival and departure of vehicles in toll plaza lanes.

Data requirements include link capacities, link speed-flow relationships, traffic signal timing plans, ramp metering cycle lengths and green times, HOV designation, real-time link surveillance, traffic volumes, origin-destination data, and roadway configuration and geometry.

The visual output of the tool is an animation of individual vehicle movements and signal control settings that are superimposed on a graphical representation of the network. This graphical interface permits the user to query the status of individual vehicles or links. A series of statistics on travel time, distance, number of stops, queue sizes, fuel consumption, and vehicle emissions are logged during each run to permit extensive post-processing of selective results. INTEGRATION network outputs include total link travel time, total network travel time, average network speed, average trip length and time per vehicle, and total and average network stops.

The light version of the tool is capable of handling a network with up to 10,000 vehicles, 100 links, 50 nodes, and 10 zones. The standard version of the tool has been used for networks of several thousand links, 500 zones and nearly 500,000 vehicles.

FREFLO

FREFLO is a component program of the CORFLO package. FREFLO was developed by FHWA and was released for microcomputer applications in 1993. FREFLO is a semi-detailed macroscopic simulation tool. Because of its less detailed simulation, the program can be used to simulate large urban freeway networks with much less execution time than some of the other microscopic simulation programs. Users can apply FREFLO to evaluate the effectiveness of alternative freeway configurations and traffic management schemes, in responding to predefined traffic flows. Using time-interval-based updates, the program has the capability to simulate multiple time periods.

FREFLO uses established relationships for entry flow rates, exit flow rates, density, and space-mean speeds on freeway segments. FREFLO is capable of handling up to 500 links and 250 nodes (intersections). Each link may have up to nine lanes. Fleet components may include carpools, cars, trucks, and buses. Merges, weaves, and lane changes cannot be modeled explicitly. The only means to model ramp metering is to constrain the capacity of a ramp link. HOV lanes can be analyzed in FREFLO.

Input requirements include entry volumes, turn percentages, link-node geometry data, link capacities, free flow speeds, and origin-destination data. All of the inputs can be entered using the TRAFEdit editor. Outputs include travel speed, travel time, delay, fuel consumption, and emissions. CORFLO has a static graphics post-processor called GCOR SCORG.

One of its major advantages is that FREFLO links can be connected directly to NETFLO 1 and 2 surface street links via an interface node. This permits an integrated corridor analysis under CORFLO.

FREQ

FREQ was developed in 1968 by the University of California at Berkeley. FREQ is a deterministic, macroscopic traffic simulation tool. It is used for simulation of freeway corridor priority lanes (FREQPL) and optimization of freeway ramp metering (FREQPE). The most recent improvements to FREQ include improved modeling of fuel consumption, emissions, modal shift, spatial shift, optimization, and improved input and output capabilities.

The simulation of FREQ responds to varying traffic demands, modal shifts, and spatial shifts through a demand-performance feedback process. Weaving and merging analysis is performed using the 1965 Highway Capacity Manual technique. FREQPL (HOV analysis tool) requires inputs such as highway section lengths, capacities, speed-flow curves, location and capacity of ramps, grades, lanes, freeway demand patterns or origin-destination data, occupancy distribution of each on-ramp, alternate route (i.e., parallel arteries) traffic flows, and HOV lane design data. The latter includes the number of lanes and the cut-off vehicle occupancy limit of the HOV lanes being evaluated. The FREQPE tool (ramp metering) requires much of the same freeway design data as FREQPL (except HOV data), plus ramp control specifications. FREQ includes a DOS graphical user interface preprocessor.

FREQPL's outputs include traffic performance measures such as travel time, delay, queue, speed, fuel consumption, and emissions. Furthermore, FREQPL also produces contour maps of up to 10 traffic performance measures and spatial and modal response tables comparing non-HOV with HOV alternatives using various traffic performance measures. FREQPE's outputs include flows, densities, v/c ratios, travel times, speeds, ramp delays, queues, cost effectiveness, fuel consumption, and vehicle noise. FREQ also has an output processor that lets the user select specific program outputs.

A limitation of FREQ is that its two programs (FREQPL and FREQPE) can't be run concurrently and there is no direct interaction between the two programs. The maximum dimension limits of FREQ, version 11, include 24 time slices, 158 freeway subsections, and 78 origins and destinations.

CORSIM/FRESIM

FRESIM is the other microscopic tool in the CORSIM simulation package. Simulation is based on a time scan with each vehicle status updated every second. Because of its microscopic, stochastic simulation, the run time of CORSIM is considerably longer than macroscopic programs such as FREFLO. CORSIM is designed to analyze operational improvements in freeway networks. FRESIM's applications in CORSIM may include: one to five thru-lane freeway mainlines with one- to three-lane ramps and one- to three-lane inter-freeway connectors; variations in grade, radius of curvature, and superelevation on the freeway; lane additions and lane drops anywhere on the freeway; freeway blockage due to incidents; work zone sections; and auxiliary lanes used by traffic to enter or leave the freeway. FRESIM does not directly model HOVs or reduced lane widths.

CORSIM provides realistic simulation of operational features such as a comprehensive lane-changing model; time-of-day and traffic-responsive ramp metering; comprehensive representation of a freeway surveillance system; representation of six different vehicle types, including two passenger car and four truck types, each with its own performance capabilities; heavy vehicle movements; differences in driver habits; and warning parameters to influence the lane-changing behavior of vehicles approaching a lane drop, incident, or off ramp.

CORSIM's input requirements include geometry and operations parameters, turn movements, entry volumes and optionally origin-destination data, and detector surveillance and ramp metering data. CORSIM's outputs include link operating statistics including total travel time, move time, delay time, total vehicle miles, density, travel speed, fuel consumption, and vehicle emissions.

FRESIM's limits within CORSIM include maximums of 10,000 vehicles, 200 links, 120 nodes, and 20 freeway segments.

CORSIM may naturally be used for microscopic simulation of freeway/surface street corridors.

SPECIAL ANALYSIS TOOLS

For the purpose of this circular, *special analysis tools* are defined as interactive time-space and platoon dispersion tools. These tools are used to generate progression solutions for coordinated arteries. The tools provide preliminary solutions to aid the traffic engineer in fine-tuning optimal green bands for either one-way or two-way arteries.

Time-space diagram programs are good tools to generate preliminary progression solutions for coordinated arteries. Frequently, local government agencies are challenged to make an improvement to exiting timing plans, most specifically to improve progression on a single or a group (network) of arteries. Generally, to achieve this goal the agency is required to collect turning movement counts at each intersection on the affected artery and subsequently use a computerized tool to predict and analyze the optimal solution for progression on the artery. A solution is usually determined as a function of the best cycle length, green splits, and offsets at each intersection that would yield the best progression bands on the artery(ies). Next comes the field work for fine-tuning the optimal solution, to accommodate for the variation in driver behavior and roadway conditions.

Although the order of these activities appears to be academically practical, it is very seldom followed by local agencies. Chief among the reasons are the lack of personnel to collect traffic volumes and lack of knowledge of computer tools. Despite these reasons, many agencies still fine-tune signal timing plans on arteries by manually preparing time-space diagrams, and subsequently performing travel-time and delay studies.

Since the early 1990s several time-space application programs have been developed to aid traffic engineers. The majority of the programs are demand-independent and only require input data such as distances between intersections, cycle length, splits, offsets, and travel speeds. With this information, the programs are able to generate a time-space diagram and allow the user to interactively manipulate the parameters. The remainder of this section presents a summary of programs available to accomplish fine-tuning of signal timing, with and without traffic volumes used as inputs to the programs. Summaries of the data input, system requirements and objective functions are shown in Tables 10 and 11.

Until recently the application of the majority of time-space programs were limited to arterial applications; namely PASSER II, PROGO, NOSTOP, and TS/PP-Draft (27, 28). In recent years, however, other programs have been developed for time-space diagram applications for both arteries and networks. These programs include SNAG, SYNCHRO, and TSDWIN. Furthermore, some of the programs such as SYNCHRO and TS/PP-Draft also have the ability to superimpose the platooning and dispersion of vehicles within the green bands.

Generally, platoon dispersion tools supplement a time-space diagram and may have additional information such as traffic volumes, queue, and stops superimposed on the time-space diagram. Programs that have both characteristics, that is, time-space and platoon progression analysis, offer an obvious advantage to the user because of the visual interaction of arrivals and queue discharge.

Applications, data and system requirements for each of the above programs are summarized in Tables 10 and 11.

TSDWIN

TSDWIN is a Windows-based graphical tool, designed to assist analysts responsible for fine-tuning signal timing plans (29). The purpose of the program is to provide a quick and easy method to achieve graphical representation of time-space diagrams for either a single artery or a group of arteries, based on existing or proposed signal timing data (cycle length, splits, offsets).

TSDWIN organizes intersections into arteries and arterial groups. The program has a capacity of 999 arteries and up to 12 intersections per artery. A combination of crossing arteries can be fine-tuned and analyzed in a single run. Timing for any intersection, including those that are common for crossing arteries, can be locked to prevent changes. Data and corresponding graphical displays may be selected in either metric or imperial units. Splits and offsets may be entered in seconds or percent. Coordination points can be referenced to either the beginning of the green or the yellow interval. The program also allows the user to select a double-cycle option for any intersection.

Data inputs required for TSDWIN include spacing and travel speeds between intersections, cycle length, splits, and offsets for all intersections. Traffic demands are not required.

The program's outputs include graphic displays of the green band and flows. The green band is color-coded and measured in seconds. A green band for both directions of traffic movements is shown if one can be calculated, based on the timing data entered by the user. If a continuous green band cannot be calculated, the link-to-link green band is presented. This allows the user to evaluate how offsets might be adjusted to achieve a continuous green band.

The directional flow displays show the calculated green band, if one exists, together with a yellow band and red band. The yellow band indicates vehicles outside the green band, but that will clear the next intersection, and the red band represents vehicles that will not clear the next intersection. TSDWIN allows the user to vary the speeds between the intersections and determine the associated impact on existing or proposed progression bands. Furthermore, using a mouse, TSDWIN provides an interactive user-interface to change the offsets, splits, and lead-lag phase orders, and it recalculates the time-space diagram parameters automatically when changed.

The database and any of the graphic displays can be printed in black and white or color. Other features of TSDWIN include its ability to import data from PASSER II, import and export delimited ASCII data, and access to context-sensitive on-line help.

NOSTOP

NOSTOP is another demand-independent bandwidth-based program. NOSTOP can be used to view time-space diagrams based on user-defined signal timing data, optimized cycle length, and offsets based on progression efficiency. It can determine the optimum cycle length and offsets for variable speeds. Minimum data input requirements include distances between intersections, green splits, directional speeds, and a range of cycle lengths.

NOSTOP provides the user with a graph of the variations of progression efficiency over a complete range of cycle lengths and progression speeds. The program selects the cycle length with the best efficiency over a user-specified range. After selecting the optimal signal timing parameters, NOSTOP calculates the green times for leading and lagging left turns at each intersection without interfering with the thru band of the coordinated phases. It calculates the unused thru green times and widens the progression band in the preferential direction. One may use the optimal time-space diagram control parameters generated by NOSTOP (cycle length, splits, and offsets) and constrain these as inputs to TRANSYT-7F for fine tuning.

NOSTOP is available in two levels: level 1 has a capacity of 12 intersections and level 2 has a capacity of 25 intersections.

TS/PP-Draft

TS/PP-Draft is an arterial-based time-space and platoon progression diagram tool. Using TS/PP-Draft the user can change control parameters such as phase sequences, splits, offsets, or cycle length, and observe an immediate change in a graphical time-space diagram. The program allows the user to select one of two types of time-space diagrams: 1) a time-space diagram with green bands showing the approximate location of the platoon, and 2) a platoon progression diagram showing the traffic flow and queue lengths.

For a detailed analysis of platoon dispersion, the program requires the following data: speeds and distances between intersections, number of thru lanes, cycle length, phase sequences, splits, right-turns-on-red, volumes, and ideal saturation flow rates. The program calculates the “actual” saturation flow rates using the method prescribed in Chapter 9 of the Highway Capacity Manual. For a display of the time-space diagram only, the program does not require any of the traffic volumes or lanes data. TS/PP-Draft allows the user to observe platoon progression flows to enhance the fine tuning capability of the program. Based on the type of arrivals, the user may easily adjust the offsets, phase sequences, or other control parameters and view an immediate change on the monitor.

TS/PP-Draft is fully compatible with the AAP, thus allowing the user to import and export AAP files. TS/PP-Draft can also import and export delimited ASCII data and provides context-sensitive, on-line help.

PROGO

PROGO (**PRO**gression **G**raphics and **O**ptimization) is an arterial-based time-space optimization program (30). The program has a limit of 20 intersections. PROGO uses a different approach to display progression than traditional time-space diagrams. It takes the traditional time-space diagram and transforms it to produce a “time-location diagram.” The user can edit the time-location diagram to iteratively produce the best solution or the program will self-optimize. Fine tuning a PROGO solution can take several forms, by changing any or a combination of the cycle length, phase sequences, offsets, or splits.

Users can run PROGO directly from within the AAP using “GDF” files created by both PASSER II and TRANSYT-7F. PROGO is a DOS program.

Data required to run PROGO include link lengths and speeds, cycle length, phase sequences, splits, and offsets. Traffic demands are not required. The program’s only measure of effectiveness is “progression opportunities” (PROS). PROS is defined as the number of progression opportunities between adjacent intersections on the artery.

SNAG

SNAG (**S**ignal **N**etwork **A**nimated **G**raphics) allows users to see the animated green bands travel through the network of coordinated arteries for up to a total of 50 intersections (31). Unlike all other two-dimensional time-space diagram tools, SNAG displays the time-space diagram in a three-dimensional network, with time being the third dimension. The animated graphics of three-dimensional time-space diagrams overcome a major deficiency of the often used two-dimensional diagrams. Its best applications can be well appreciated when using the program to evaluate progression on multiple arteries. SNAG provides engineers and managers with a cost-effective tool to evaluate the quality of any signal timing design in the network. It answers the typical signal timing "What if" questions. Further, it serves as a good PR tool by showing animated graphics of systems at work. SNAG is a DOS program.

To generate a display of a three-dimensional time-space diagram SNAG requires the following data: X-Y coordinates of intersections, phase sequences, link speeds, and signal timing, including system cycle length, splits, and offsets. Traffic demands are not required.

To evaluate the effectiveness of progression solutions SNAG uses an efficiency rating (performance index, or PI) similar to PASSER II. The PI is calculated by summing the proportion of each link that falls into a progression band for each of 50 intervals (or 2% of the cycle). The user can assign link weights as a multiplier so that the PI can be higher if good progression exists on the links that are assigned the highest weight. Users can plot static displays of the screen graphic of the time-space diagram.

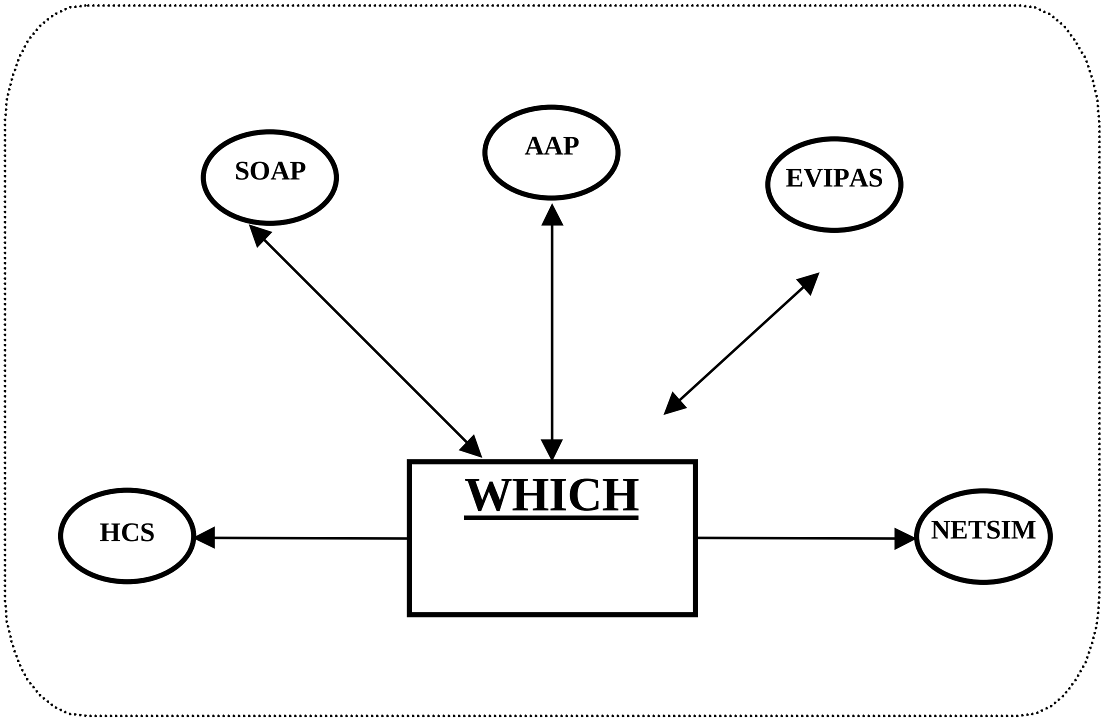
INTEGRATION OF TOOLS

Integration of tools refers to utilities that use a common data entry format for two or more programs. Instead of learning several data editors for various programs, integrator utilities allow the user to enter the data only once and subsequently run several programs of the user's choice. Below are descriptions of the most commonly used integrators for isolated intersections, arteries, and networks.

A number of Windows-based integration tools are currently, or soon to be, underway. The Traffic Software Integrated System (TSIS), described later in this section, will increasingly become a computing platform for traffic analysis tools. While some of the integrators described below (notably AAPEX and WHICH) will be functionally replaced within a year or two, they remain in wide use today.

WHICH

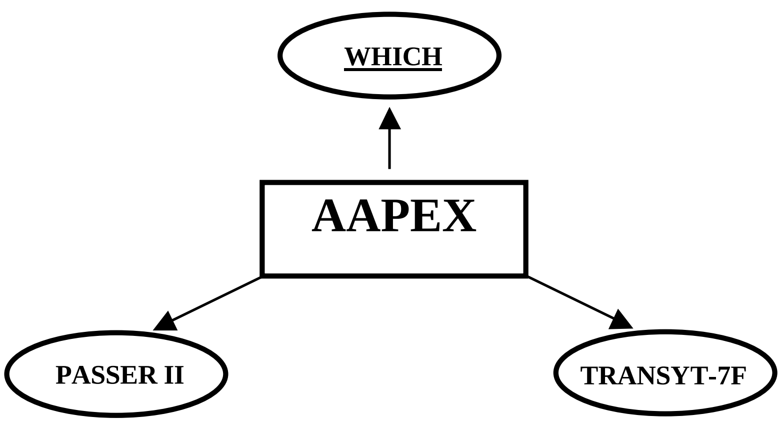
WHICH, the **W**izard of **H**elpful **I**ntersection **C**ontrol **H**ints, is an integrator tool that integrates traffic control design parameters for isolated intersections and arteries into one common data set. By doing so, the user can run several programs without getting into their data editors. WHICH interacts with several component programs such as SOAP, HCS, TRAF-NETSIM and several other non-signalized programs (32). Also, WHICH may be linked with the AAP. Some programs, such as TRAF-NETSIM, may require additional data entry from their own data editors, depending on the specific application. Users should note that WHICH has the capability to run TRAF-NETSIM only for isolated intersections. TRAF-NETSIM, and HCS are not distributed with WHICH. (Note: since NETSIM has been merged into CORSIM, new users can only obtain an unsupported version of the older TRAF-NETSIM to use with WHICH.)



AAPEX

AAPEX is an acronym for Arterial Analysis Package Executive (33). It provides convenient access to two of the most popular traffic signal timing tools : PASSER II and TRANSYT-7F.

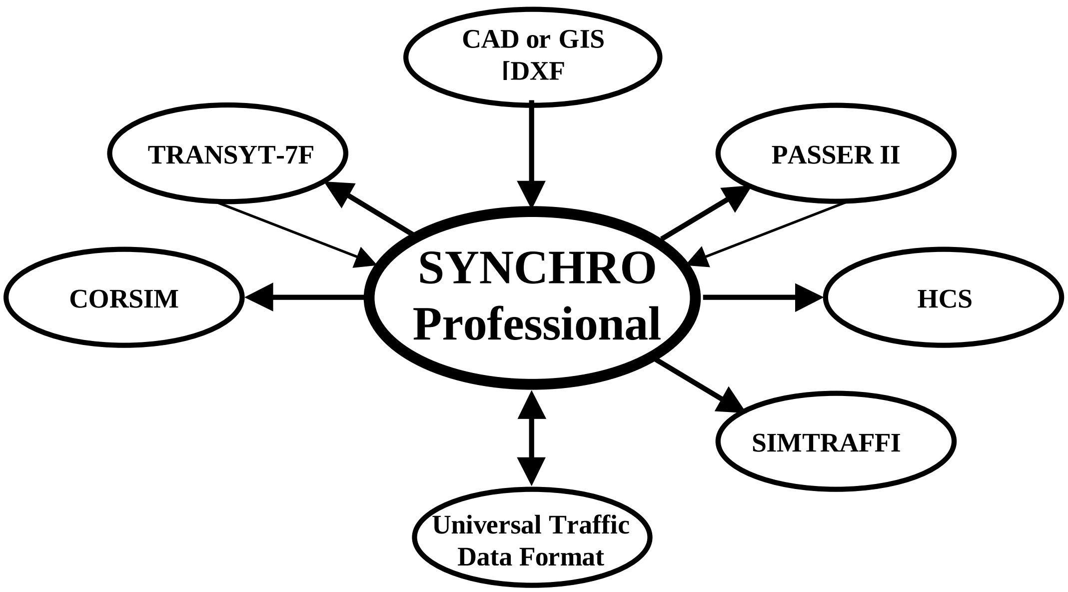
The data entry scheme of AAPEX (a DOS program) is applicable to only arteries and does not include data entry information for analysis of networks using TRANSYT-7F. AAPEX has a post-processor that allows the user to view the results of both PASSER and TRANSYT-7F.



SYNCHRO

SYNCHRO, a Windows-based program, integrates its common data set with four of the most popular traffic signal timing programs: PASSER II, TRANSYT-7F, HCS (signalized intersections only), and CORSIM (TRAF-NETSIM only). By entering the data only once using a point and click data entry scheme, SYNCHRO can perform its own analysis and optimization and also provides the user with a choice to transfer the data to and run any of these programs with no additional data entry. With arteries and grid networks, SYNCHRO allows the user to transfer individual intersection data into the HCS-Signalized intersection module (the DOS version), thus creating .HCS-Signals files automatically.

Besides the above, SYNCHRO also has the ability to import the outputs of PASSER II and TRANSYT-7F, so that interactive fine-tuning of time-space and platoon-dispersion diagrams can be made.



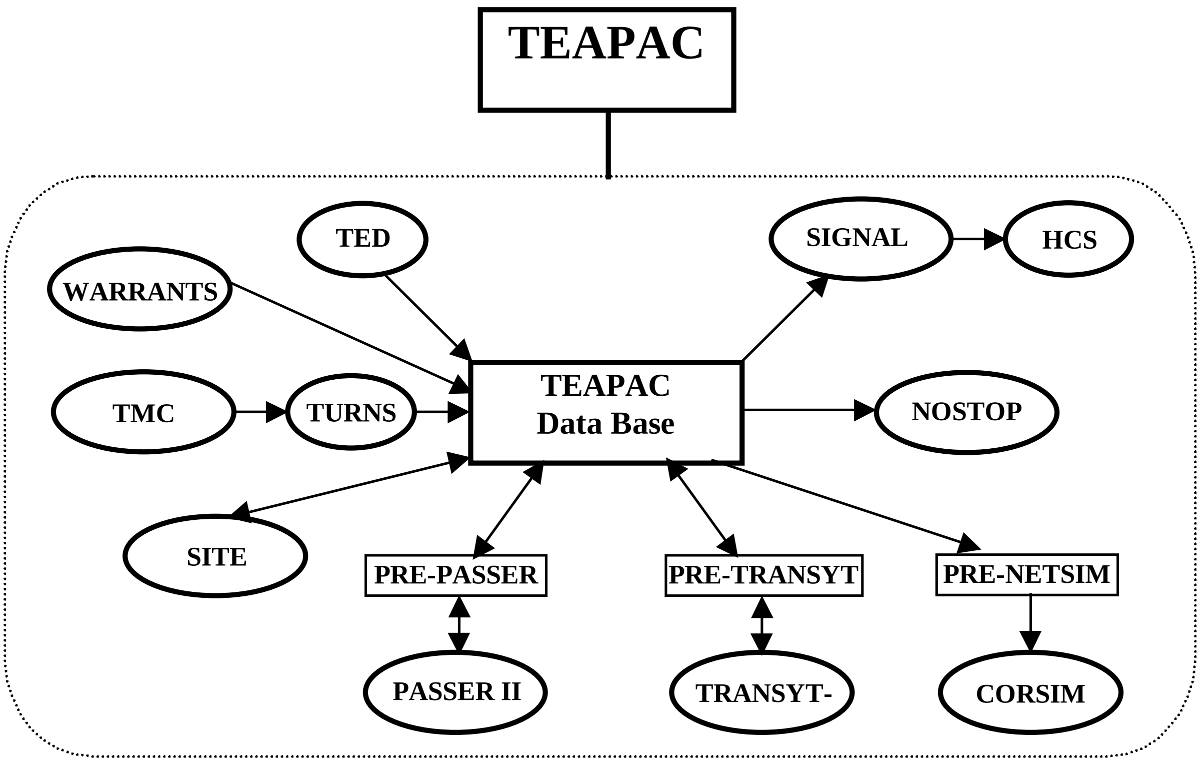
TEAPAC

TEAPAC is an acronym for **T**raffic **E**ngineering **A**pplication **PAC**kage (34). It is an integrated system of programs designed to perform many common traffic engineering analyses. Each of the programs in the package provides the same full-screen user interface and is driven by a common set of commands. Each program can be used interactively via a menu system or manual commands, and also allows for batch execution of large or multiple analyses.

The Signal Timing Analysis Package subset of TEAPAC consists of SIGNAL97, NOSTOP, PREPASSR, PRETRANSYT, and PRENETSIM. This package provides complete signal timing for individual signals, arteries, and networks. PREPASSR, PRETRANSYT, and PRENETSIM, used as preprocessors, utilize the SIGNAL97 data files to produce input files for PASSER-II, TRANSYT-7F and CORSIM without further data input, except for the actuated controller cards with CORSIM. PASSER, TRANSYT and CORSIM must be purchased separately.

The Site Impact Analysis Package subset of TEAPAC consists of the SITE, SIGNAL97, NOSTOP, TURNS, and WARRANTS programs. These provide complete site traffic estimation, capacity analysis, and intersection/signal design for traffic impact studies. SITE estimates traffic from a single-use or multi-use development, using existing traffic counts from TURNS and intersection descriptions from SIGNAL97's capacity analysis of existing conditions. The projected volumes of SITE are transferred directly to SIGNAL97 for capacity analysis and iterative intersection/signal design, using SIGNAL97's optimization feature.

TEAPAC is available as both DOS and Windows applications.

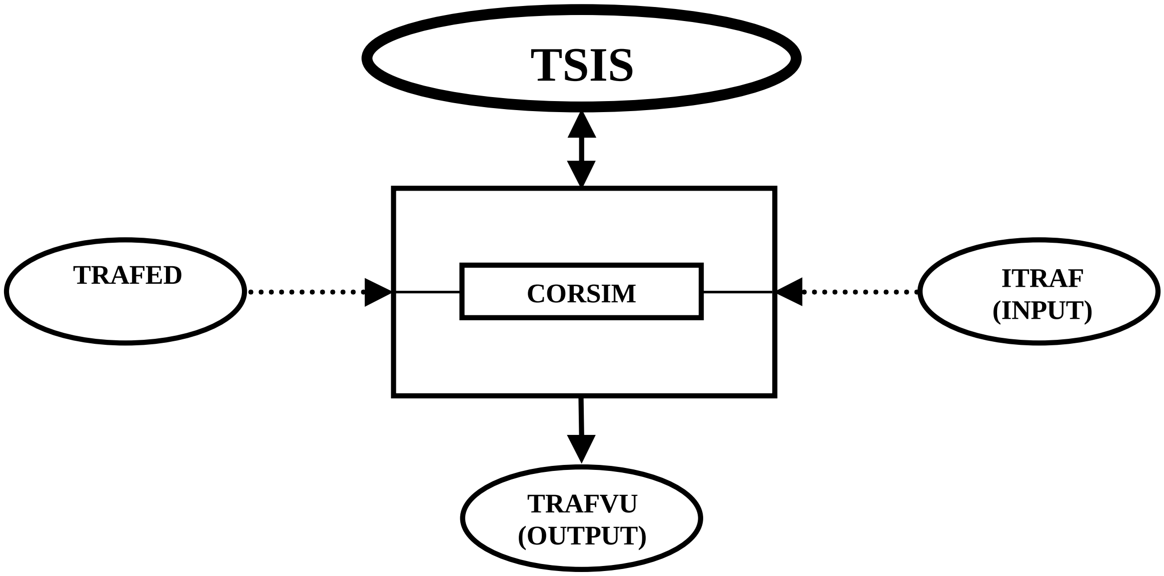


TSIS

TSIS is an acronym for Traffic Software Integrated System (35). Developed by the FHWA, it provides a state-of-the-art Windows 95/NT based environment for FHWA's family of TRAF traffic engineering, analysis, and simulation tools. TSIS integrates with the microscopic TRAF tools of CORSIM, namely FRESIM for freeway simulation and NETSIM for surface arteries and network simulation. Users now can integrate arterial and freeway applications using one common data set.

Some of the TSIS's component programs besides CORSIM includes TRAFVU and TRAFED. TRAFVU is an output processor for animating CORSIM results. TRAFVU replaces the formerly known GTRAF DOS-based post processor. TRAFED is the graphical input processor for CORSIM (in preparation at this writing).

An interim input data processor (that also supports CORFLO) is separately available. It is called ITRAF.



AVAILABILITY OF SOFTWARE AND TECHNICAL SUPPORT

Table 12 lists the availability and telephone numbers for technical support to all of the discussed tools.

The majority of software is available from Mc*Trans* and PC-TRANS. Their addresses are listed as follows:

Mc*Trans*
Center for Microcomputers in Transportation
University of Florida
512 Weil Hall
P.O. Box 116585
Gainesville, FL 32611-6585
Tel: (800) 226-1013 for messages
(352) 392-0378 ext.1 for technical support
E-mail: mctrans @ ce.ufl.edu
Web Site: http://mctrans.ce.ufl.edu

PC-TRANS
University of Kansas
Transportation Center
2011 Learned Hall
Lawrence, KS 66045
Tel. (913) 864-5655 for technical support
Fax (800) 245-8760 for technical support
E-mail: Pctrans@kuhub.cc.ukans.edu
Web Site: http://kuhub.cc.ukan.edu/~pctrans

Traffic signal timing and traffic operations courses are also offered by the following agencies:

Agency	Telephone Number
National Highway Institute, Arlington, Virginia	(703) 235-0525
University of Florida, Gainesville, Florida	(352) 392-0378 x 1
Georgia Institute of Technology, Atlanta, Georgia	(404) 894-2547
Northwestern University, Illinois	Fax: (847) 491-5270
Trafficware, Inc., Berkeley, California	(510) 526-5891
Strong Concept, Illinois	(847) 564-0386
University of Central Florida, Orlando, Florida	(407) 823-6110
University of Wisconsin, Wisconsin	(800) 462-0876
ARRB Transport Research Ltd., Australia	Fax: +613 9887 8104

Many of the courses are offered on a per request basis, and the contents of the courses tend to change frequently to include either new revisions to traffic tools or additions of new tools and pertinent theory. It is suggested that maintaining and operating agencies contact the agencies in the above list to obtain specific information about the offered training courses, status, fees, prerequisites, and availability.

NOTES AND REFERENCES

1. The first was called "Handbook of Traffic Operations Analysis," and was developed for FHWA by Dias-Seckenger, Associates, with the assistance of Charles Wallace and Ken Courage of the University of Florida, in 1982. It covered mainframe packages.
2. Mekemson, J.R., "Traffic Models Overview Handbook," published by the Federal Highway Administration, VICOR Associates, Inc., Washington, D.C., June 1993.
3. Although computer programs are often referred to as "models," they are, strictly speaking computerized applications of (often) many traffic models. Models are the algorithms and processes. To avoid confusion, this circular refers to "models" in the sense of a process, and "tool" or "package" for computer programs.
4. See front matter for the task force membership.
5. See the glossary of terms in the appendix for definitions of common acronyms.
6. One such offer was made but was rejected as not yet operational or publicly available.
7. For a comprehensive coverage of integrated design and analysis processes, see the Methodology

for Optimizing Signal Timing (M|O|S|T) documentation (COURAGE & WALLACE, 1991).
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19. Wallace, C. E., K. G. Courage, M. A. Hadi and A. Gan, "Methodology for Optimizing Signal Timing (M|O|S|T), Volume 4: TRANSYT-7F Users Guide," Prepared for the Federal Highway Administration, COURAGE & WALLACE, Gainesville, FL, updated March 1998.
20. Husch, D., "Synchro 3.2 User Guide," Trafficware, Berkeley, CA, 1993-1998.
21. Chaudhary, N.A. and C.J. Messer, "PASSER IV-96 Version 2.1 User/Reference Manual," Texas Transportation Institute, College Station, TX, October 1996.
22. EZ-TRANSYT-PLUS, Quick-7F, and PRETRANSYT are all commercially available DOS preprocessors for TRANSYT-7F. While not explicitly covered in this circular, they are mentioned here because of their value in using TRANSYT-7F. All greatly enhance the input processing for the tool.

TABLE 1 Intersection-Based Programs: Applications and Characteristics

Program	Applications							Animation		Measures of Effectiveness					
	Evaluate Existing Timing	Optimize Phase Sequence	Optimize Cycle Length	Optimize Splits	HCS LOS	Lane-by-Lane Analysis	Actuated Control	Dynamic	Passive	LOS	Delay[2]	Fuel Consumption	Emissions	Queue[3]	Stops
HCS-Signals	√	No	No	No	√	No	√[1]	No	No	√	SD	No	No	No	No
HCM/CINEMA	√	No	No	No	√	No	√[1]	√	√ -	√	TD	√	√	√	√
SOAP	√	No	√	√	No	No	√[1]	No	No	No	SD	No	No	Yes	No
SIGNAL97	√	√	√	√	√	No	√[1]	No[4]	√	√	TD, SD	√	√	√	√
SIDRA	√	√	√	√	√	√	√	No	√	√	SD, TD*	√	√	√ [5]	√
TEXAS	√	No	No	No	No	√	√	√	√	No	√	√	√	MQL	√
EVIPAS	√	No	√	√	No	√	√	No	No	No	TD, SD	√	√	No	√

[1] Limited logic for vehicle actuation; does not emulate actual controller operation
[2] SD: stopped delay, TD: total delay
[3] MQL: maximum queue length
[4] Connects to CORSIM via PRENETSIM
[5] SIDRA produces 90th, 95th and 98th percentile queues for the cycle-average queue and maximum back of queue.
* SIDRA produces stopped delay, queuing delay and geometric delay caused by speed reduction.

TABLE 2 Intersection-Based Programs: Data and Systems Requirements

Program	Data Input Requirements						Operating System		Minimum Hardware Requirements					
	Traffic Volumes	Geometry	Traffic & Roadway Conditions	Signal Phasing & Timing			DOS	Windows	PC Platform	Hard Disk Space (MB)	Ext. Memory (MB)	Monitor	Mouse	Math-Copr.
				Cycle & Splits	Phase Sequence	Actuation								
HCS-Signals	R	R	R	R	R	O	N/A[1]	95/NT	486	1	16	EGA/VGA	O	O
HCM/ CINEMA	R	R	R	R	R	O	3.1	R	AT	3	640 KB		O	O
SOAP	R	R	R	R	R	O	3.0	N/A	AT	1	640 KB	CGA	N/A	O
SIGNAL97	R	R	R	O	O	O	3.0	3.1, 95, NT	AT	1	640 KB (DOS)	EGA/VGA	O	O
SIDRA	R	R	R	O	O	O	N/A	R	386	10	4	VGA	O	R
TEXAS	R	R	R	R	R	O	3.0	N/A	386	4	8	EGA/VGA	O	R
EVIPAS	R	R	R	[2]	R	O	3.0	N/A	386	4	4	EGA/VGA	O	R

R- required; O- optional; N/A- not applicable

[1] The DOS version is being phased out in mid 1998.

[2] Phase data such as the number of vehicle and pedestrian phases and signal timing data are required.

TABLE 3 Arterial-Based Programs: Applications and Characteristics

Program	Applications								Animation		Measures of Effectiveness					
	Evaluate Existing Timing	Optimize Phase Sequence	Optimize Cycle Length	Optimize Offsets	Optimize Splits	Optimize HCS LOS	Lane-by-Lane Analysis	Actuated Control	Dynamic	Static	LOS	Delay[2]	Fuel Consumption	Emissions	Queue[3]	Stops
HCS-Arterials	√	No	No	No	No	No	No	√[1]	No	No	√	SD, TD	No	No	No	No
HCS-Multilane	N/A	N/A	N/A	N/A	N/A	No	No	N/A	No	No	√	No	No	No	No	No
PASSER II-90	√	√	√	√	√	No	No	√[1]	√	√ -	√	TD	√	No	MQL	√
PASSER III-90	√	NO	√	√	√	No	No	No	No	√ -	√	TD	No	No	SR	No

[1] Limited logic for vehicle actuation; does not emulate actual controller operation
[2] TD: total delay
[3] MQL: maximum Queue length
√: Partial static animation
SR: Storage Ratio
N/A: Not applicable

TABLE 4 Arterial-Based Programs: Data and System Requirements

Program	Data Input Requirements					Operating System		Minimum Hardware Requirements					
	Traffic Volumes	Traffic & Roadway Conditions	Signal Phasing & Timing			DOS	Windows	PC Platform	Hard Disk Space (Mb)	Memory	Monitor	Mouse	Math-Copr.
			Cycle & Splits	Phase Sequence	Actuation								
HCS-Arterials	R	R	R	R	O	N/A	95/NT	486	1	16MB	EGA/VGA	O	O
HCS-Multilane	R	R	N/A	N/A	N/A	N/A	95/NT	486	1	16MB	EVA/VGA	O	O
PASSER II-90	R	R	O	O[1]	O	3.1	N/A	AT	1	640 KB	CGA	N/A	O
PASSER III-90	R	R	O	R	N/A	2.0	N/A	8088	1	512 KB	CGA	N/A	O

R- required; O- optional; N/A- not applicable

TABLE 5 Network-Based Programs: Applications and Characteristics

Program	Applications								Animation		Measures of Effectiveness					
	Evaluate Existing Timing	Optimize Phase Sequence	Optimize Cycle Length	Optimize Offsets	Optimize splits	Optimize HCS LOS	Lane-by-Lane Analysis	Actuated Control	Dynamic	Static	LOS	Delay[2]	Fuel Consumption	Emissions	Queue[3]	Stops
PASSER IV	No	√	√	√	√	No	No	No	No	√	√	TD	√	No	No	No
TRANSYT-7F	√	No	√	√	√	No	√	√[1]	No	√	√	TD	√	No	MBQ	√
SYNCHRO	√	√[8]	√	√	√	√	No	√	No	√	√	TD	√	No	MQL	√
CORSIM	√	No	No	No	No	No	No	√	√	No	No	TD	√	√	√[5]	√[4]
NETFLO 1	√	No	No	No	No	No	No	√	√	No	No	TD	√	√	√[6]	√
NETFLO 2	√	No	No	No	No	No	No	No	√	No	No	TD	√	√	√[7]	√

[1] Limited logic for vehicle actuation; does not emulate actual controller operation
[2] SD: stopped delay, TD: total delay
[3] MBQ: maximum back of queue , MQL: maximum queue length
[4] In percent
[5] Average and maximum queue length
[6] By lane
[7] By movement
[8] Left-turn phase orders only (lead-lag)

TABLE 6 Network-Based Programs: Data and System Requirements

Program	Data Input Requirements					Operating System		Minimum Hardware Requirements					
	Traffic Volumes	Traffic & Roadway Conditions	Signal Phasing & Timing			DOS	Windows	PC Platform	Hard Disk Space (MB)	Memory (MB)	Monitor	Mouse	Math-Copr.
			Cycle & Splits	Phase Sequence	Actuation								
PASSER IV	R	R	O	O	N/A	3.1	N/A	8088	1	570 KB	CGA	O	O
TRANSYT-7F	R	R	O[3]	R	O	5.1	95/NT	486	2	640 KB	EGA/ VGA	N/A[1]	O
SYNCHRO	R	R	O[3]	R	O[4]	3.1	R	486	10	8	VGA	R	O
CORSIM/ NETSIM	R	R	R	R	O	N/A	R	486	20	16	EGA/ VGA	O	R
NETFLO 1	R	R	R	R	O	5.0	N/A	AT	20	8 MB[2]	EGA/ VGA	O	R
NETFLO 2	R	R	R	R	N/A	5.0	N/A	AT	20	8 MB[2]	EGA/ VGA	O	R

[1] Optional for McT7F, a pre- and post-processor distributed with TRANSYT-7F
[2] Extended memory
[3] Required for evaluation
[4] Required for optimization of actuated controllers
R- required O- optional N/A-notapplicable

TABLE 7 Comparison of TRAF Network Tools

Measure	CORSIM	NETFLO 1	NETFLO 2
Fleet components	Cars, Carpools, Buses, Trucks	Cars, Carpools, Buses, Trucks	Cars, Buses, Trucks
Turn movements	√	√	√
Bus operations (stations, flow volumes, dwell times and routes)	√	√	√
HOV lanes	√	√	√
Queue discharge distribution	√	√	Not applicable
Control (fixed-time, actuated signal control, stop signs, yield signs)	√	All but dual ring actuated control	All but single and dual ring actuated control
Maximum number of approach lanes	7	6	6
Incident and temporary events	√	Blockage factor	Blockage factor

TABLE 8 Freeway-Based Programs: Applications and Characteristics

Program	Applications						Animation	Measures of Effectiveness							
	Evaluate Lane Configuration	Ramp Metering	Freeway/ Arterial Integration	Evaluate Incident Management	HOV Lanes	Lane-by-Lane Analysis		LOS	Travel Speed	Delay	Travel Time	Fuel Consumption	Emissions	Queue	Stops
HCS-Freeways	√	No	No	No	√	No	No	√	√	No	No	No	No	No	No
INTEGRATION	√	√	√	√	√	No	√	No	√	No	√	√	√	√	√
CORFLO FREFLO	√[1]	√	√	√	√	√	√	No	√	√	√	√	√	No	No
FREQ	√	√	No	No	√	√	No	No	√	√	√	√	√	√	√
CORSIM/FRESIM	√	√	√	√	√[2]	√	√	No	√	TD	√	√	√	No	No

[1]by constraining on-ram link capacity. [2]FRESIM does not model HOV lanes; however, the user can approximate HOV lane operation by coding it as a separate parallel freeway.

TABLE 9 Freeway-Based Programs: Data and System Requirements

Program	Data Input Requirements		Operating System		Minimum Hardware Requirements					
	Traffic Volumes	Geometry	DOS	Windows	PC Platform	Hard Disk Space (MB)	Memory (MbB	Monitor	Mouse	Math-Copr.
HCS-Freeways	R	R	N/A	95/NT	486	2	16	EGA/VGA	O	O
INTEGRATION	R	R	6.0	N/A	486	200	4[1]	VGA	O	R
FREFLO	R	R	5.0	N/A	386	20	8[1]	EGA/VGA	O	R
FREQ	R	R	5.0	N/A	386	200	8[1]	VGA	R	R
CORSIM/FRESIM	R	R	N/A	√	486	200	16[1]	EGA/VGA	R	R

[1] Extended memory
R- required O- optional N/A- not applicable

TABLE 10 Special Analysis Programs: Data and System Requirements

Program	Data Input Requirements									Operating System		Minimum Hardware Requirements					
	Traffic Volumes	Geometry	Speed	Distances	Signal Phasing & Timing					DOS	Windows	PC Platform	Hard Disk Space (MB)	Memory (KB)	Monitor	Mouse	Math-Copr.
					Cycle	Splits	Phase Sequence	Offsets	Actuation								
NOSTOP	No	No	O	R	O	R	R	O	No	3.0	N/A	AT	1	640	EGA	N/A	O
TSDWIN	No	No	R	R	R	R	R	O	No	3.1	R	80386	2	640	EGA	R	O
TS/PP-Draft	O	O	R	R	R	R	R	O	No	3.1	R	8088	1	512	CGA	O	O
PROGO	No	No	R	R	R	R	R	O	No	2.0	N/A	8088	1	256	CGA	N/A	O
SNAG	No	No	R	R	R	R	R	O	No	2.0	N/A	8088	1	256	CGA	N/A	O

R- required O- optional N/A- not applicable

TABLE 11 Special Analysis Programs: Applications and Characteristics

Program	Applications							Animation		Measures of Effectiveness					
	Evaluate Existing Timing	Optimize Phase Sequence	Optimize Cycle Length	Optimize splits	Optimize HCS LOS	Lane-by-Lane Analysis	Actuated Control	Dynamic	Passive	LOS	Delay	Fuel Consumption	Emissions	Queue	Stops
NOSTOP	√	P	√	No	No	No	No	No	√	No	No	No	No	No	No
TSDWIN	√	P	No	I	No	No	No	No	√	No	No	No	No	No	No
TS/PP-Draft	√	P	I	I	No	No	No	No	√	No	No	No	No	No	No
PROGO	√	I	I	No	No	No	No	No	√	No	No	No	No	No	No
SNAG	√	I	I	No	No	No	No	√	√	No	No	No	No	No	No

P: Partial I: Requires operator intervention

TABLE 12 Availability of Software and Technical Support

Program	Availability	Technical Support
HCS	MCT & PCT	MCT & PCT
HCM/CINEMA	MCT, PCT & KLD & Associates	MCT, PCT & (800) 324-8964
SOAP	MCT & PCT	MCT & PCT
SIGNAL 97	MCT, PCT & Strong Concepts	MCT, PCT & (847) 564-0386
SIDRA	MCT, PCT & ARRB TR	MCT, PCT & Fax (613) 9887-8104 e-mail: rahmia@arrb.org.au
EVIPAS	MCT, PCT	MCT, PCT
TEXAS	MCT & PCT	MCT, PCT & (512) 471-4549
PASSER II	MCT, PCT	MCT, PCT & (409) 845-9872
PASSER III	MCT, PCT	MCT, PCT & (409) 845-9872
PASSER IV	MCT, PCT	MCT, PCT & (409) 845-9872
TRANSYT-7F	MCT & PCT	MCT & PCT
SYNCHRO	MCT, PCT & Trafficware	(510) 526-5891 West Coast (410) 381-9313 East Coast
CORSIM	MCT & PCT	MCT, PCT
INTEGRATION	MCT	MCT
CORFLO FREFLO	MCT & PCT	MCT, PCT & (703) 471-0838
CORSIM NETFLO 1 & NETFLO 2	MCT & PCT	MCT & PCT & (703) 471-0838
NOSTOP	MCT, PCT & Strong Concepts	MCT, PCT & (847) 564-0386
TSDWIN	FORTRAN	(800) 265-1197, (416) 288-1320
TS/PP-DRAFT	MCT & PCT	(408) 372-1069
PROGO	MCT & PCT	MCT
SNAG	MCT & PCT	MCT

TTI: Texas Transportation Institute

MCT Mc*Trans*, Tel. (352) 392-0378
PCT: PC-TRANS, Tel. (785) 864-5655

ARRB TR: ARRB Transport Research Ltd.
500 Burwood Highway
Vermont South, Victoria 3133,
AUSTRAILIA

Trafficware
1442 A Walnut St., #210
Berkeley, CA 94709
(800) 379-6247

FORTRAN
470 Midwest Road
Scarborough, Ontario MIP-4Y5
(800) 387-4555 (Canada)

Strong Concepts
15 Timber Lane
Northbrook, IL 60062
(847) 564-0386

TS/PP-Draft
757 Bayview Avenue
Pacific Grove, CA 93950

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