Abridgment

Development of a TRANSYT-Based Traffic Simulation Model

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The Level II urban traffic simulation model contained within the TRAFLO traffic simulation package is described. Level II is a tool by which to evaluate transportation system management strategies and is an adaptation of the traffic flow model embedded in the TRANSYT signal optimization program. The Level II model describes traffic flow patterns in the form of statistical histograms. These histograms express flow rate as a function of time on each network link, stratified by turning movement; buses are treated in somewhat more detail. Platoon dispersion is treated explicitly, and service rates at an intersection are related to turning movements and to the signal control. The flow model used in TRANSYT is discussed along with the modifications and extensions that were incorporated in Level II. Data requirements and the measures of effectiveness generated by Level II are presented. Model validation results and program efficiency are also discussed.

This paper describes the Level II urban traffic simulation model contained within the TRAFLO traffic simulation package (1). Level II is a tool for evaluating transportation system management (TSM) strategies and is an extension of the traffic flow model embedded in the TRANSYT signal optimization program (2). The TRANSYT program models traffic flow on a network represented by "nodes" (intersections) that are connected by unidirectional "links" (one-way portion of a roadway).

The average pattern of traffic flow past a point on a network link is represented by a statistical histogram that relates flow rate to time (see Figure 1). All calculations are carried out by the manipulation of such histograms; no representation of individual vehicles is made.

A major conceptual difference between Level II and TRANSYT is the treatment of the independent variable, time. Whereas TRANSYT is a quasi-steady-state model, Level II is a dynamic simulation model that accommodates time-varying traffic demands and turn percentages and fixed-time signals of arbitrary cycle lengths. Traffic conditions generally vary from one "time interval" of specified duration to the next.

DESIGN OF LEVEL II SIMULATION MODEL

The key to the Level II model is the histogram representation of traffic flow at points along a link (see Figure 2).

The ENTRY flow histogram describes the entering traffic flow as seen by an observer at the entry point (upstream end) of a link. An INPUT flow histogram represents the time-varying pattern of arriving traffic as seen by an observer just upstream of the stop line. An OUTPUT histogram indicates the pattern of discharging traffic as seen by an observer just downstream of the stop line.

In addition to these flow histograms, the Level II model constructs two other types of histograms: a SERVICE histogram that represents the time history of service rates provided by the control device at the downstream intersection and a QUEUE histogram that describes the time history of the number of vehicles queued at the stop line.

Each histogram is constructed by the model for each turn movement component of traffic over one time interval; a simulation run extends over a sequence of many time intervals. During each time interval, the model computes the various histograms successively for each link in the network. Continuity of flow from one link to the next is modeled by aggregating the turn-movement-specific OUTPUT histograms of all feeder links to build the ENTRY histogram of the receiving link.

In this scheme, a link cannot have a complete ENTRY histogram unless all feeders are processed first. In a grid network, it is not possible to satisfy this requirement. So a link-sequencing algorithm was developed that guarantees that at least one feeder of each link will be processed first and ensures that most links will have all of their feeders processed first. This eliminates the need to specify "dummy" links, as was done in the TRANSYT program. Since the Level II simulation is designed to describe a dynamic traffic environment, the time lag (i.e., travel time) experienced by traffic as it moves from the upstream node of a link to the stop line must be explicitly represented. The concept of an influence zone represents this time lag explicitly.

The influence zone ABCD shown in Figure 3 contains all traffic arriving at the stop line during the current time interval. The length of this zone is the length of the street, and its width reflects the duration of the time interval. The parallel sides, AD and BC, represent free-flow vehicle trajectories whose slopes are equal to the free-flow speed $\bar{u}$. The pattern of traffic arriving at the stop line during the current time interval reflects only the pattern of traffic that enters the street within the influence zone (between time points A and B) and that portion from the prior influence zone that was not discharged.

It is necessary to process the known ENTRY histograms in order to construct the required histogram that represents traffic entering the influence zone along line AB. Figure 3 shows that the ENTRY histogram can be subdivided into several "flow regimes". These are described below:

1. Regime F_1 is defined by the aggregation of all the known turn-movement-specific OUTPUT histograms representing the traffic discharged from all feeder links during the current time interval.
2. Regime F_2 of the ENTRY histogram was "left over" from the ENTRY histogram aggregated during the prior time interval.
3. Regime F_3 describes the traffic flow pattern that lies within the influence zone at the upstream end of the subject link. Note that this histogram is formed by concatenating the F_2 regime with the early portion of the F_1 regime. This traffic will disperse as it travels along the street and will arrive at the stop line to form the INPUT histogram within the current time interval.

The influence-zone concept is applicable to any traffic environment and control policy and is therefore suitable for a general-purpose traffic simulation model.

The processing of traffic on a link involves several activities:

Figure 1. Representation of platoon structure in TRANSYT.

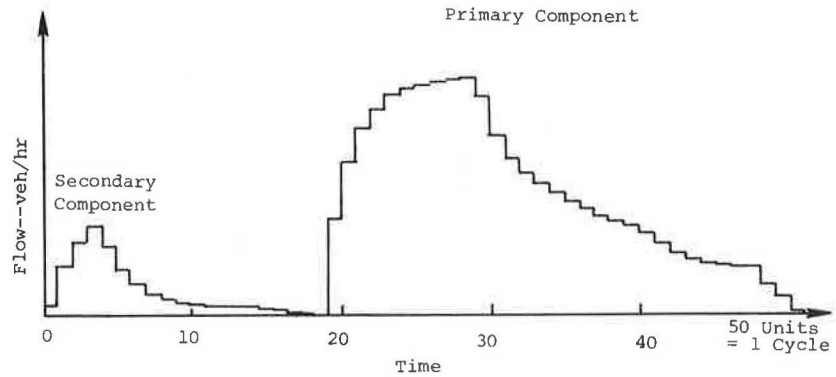
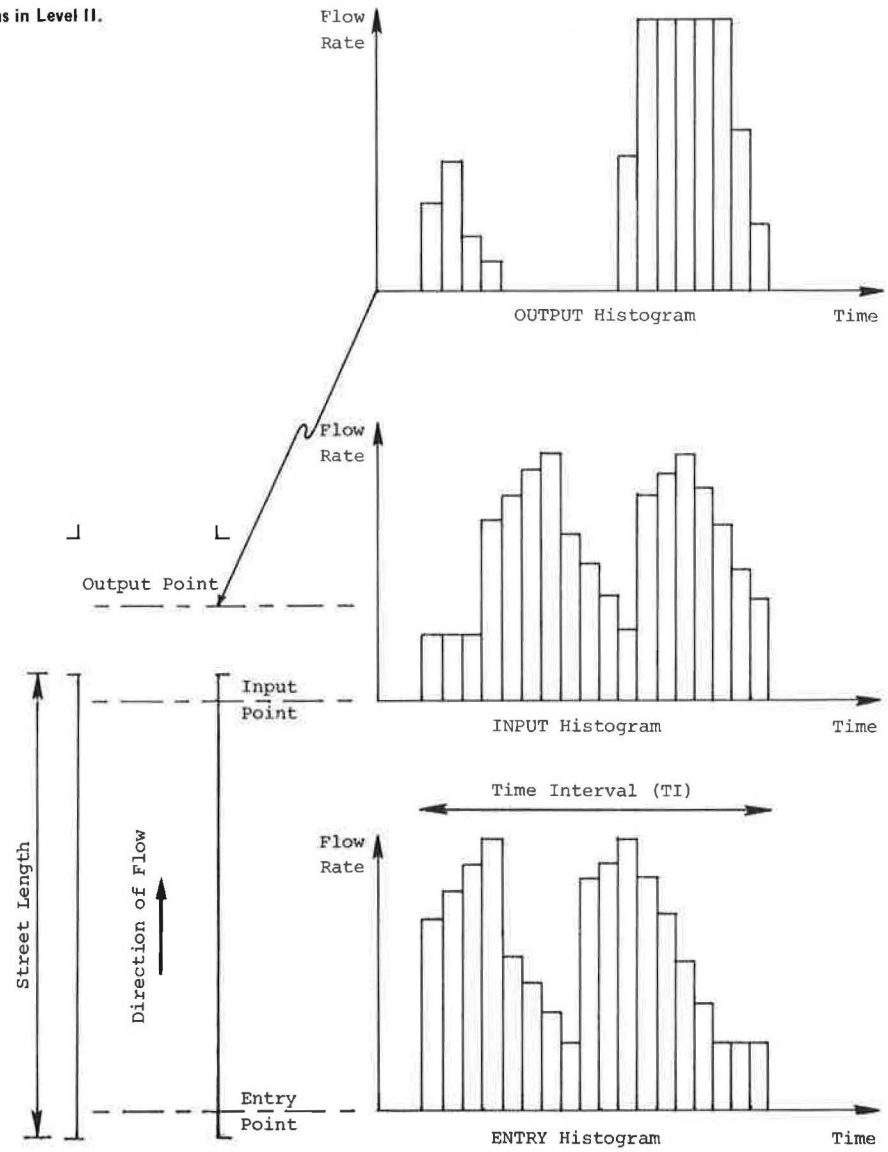
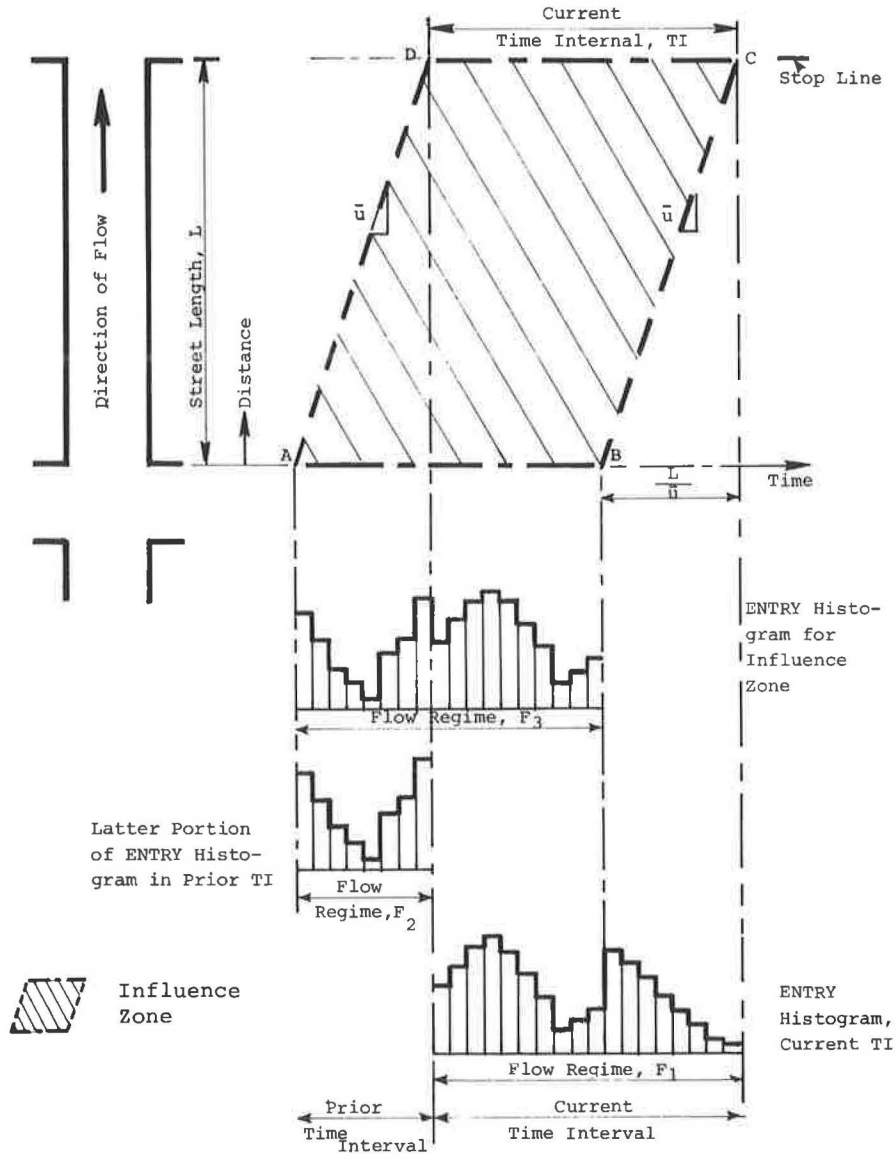


Figure 2. Flow histograms in Level II.



1. Form the ENTRY histogram for traffic entering the influence zone (regime F_3), as described above.
2. Disaggregate this histogram (regime F_3) into turn-movement-specific components.
3. Store that portion of the original ENTRY histogram (regime F_1) that lies beyond the influence zone for subsequent use in the next time interval (this portion becomes regime F_2 for the next time interval).
4. Calculate the respective INPUT histograms (Figure 2) by applying the platoon-dispersion relation developed by Robertson and used in TRANSYT (2).
5. Generate a SERVICE histogram for each

Figure 3. Space-time representation of influence-zone concept.



movement. These histograms represent the service rates permitted by the control. These service rates are computed by a new capacity model (described in papers by Lieberman and by McShane and Lieberman elsewhere in this Record).

6. Transform each turn-movement-specific INPUT histogram into its counterpart OUTPUT histogram. This transformation reflects the interaction of each INPUT histogram with its respective SERVICE histogram. In the process, a time history of vehicle queues (QUEUE histogram) is produced to facilitate the computation of vehicle stops and delays.

Vehicle delays, vehicle stops, and the random component of delay are computed by using the TRANSYT concepts described in detail by Robertson (2). Continuity of flow is carefully preserved between adjoining time intervals.

Input

The Level II model requires a detailed network description to accurately represent traffic flow. Data requirements include geometrics, traffic operating characteristics, traffic control specifications, traffic demand volumes, turning movements on each link, and mass transit data.

The user may specify certain time-varying data: lane channelization, entering traffic volumes, intralink source-sink volumes (from-to parking facilities), link-specific turn percentages, and bus headways and station dwell times. To improve the ability of the model to accept these time-varying data, the concept of a user-specified time period was developed. A time period consists of a sequence of time intervals. During a time period, all input data remain fixed. At the end of each period, the user may specify any changes in the above parameters.

Output

The Level II model offers a wide range of statistics. The output generated by the model is the "measures of effectiveness" used by traffic engineers to evaluate management strategies.

Cumulative output of both (a) networkwide link-specific and (b) bus-route-specific measures is provided at the end of each time period. More frequent and more detailed output can be requested by the user.

REPRESENTATIVE RESULTS

The TRAFLO Level II model was validated on a network in downtown Washington, D.C., that consisted of 96 links and 51 nodes and represented a wide range of geometrics. Validation runs were made for morning peak and off-peak periods, and a wide range of turn movements and traffic volumes was reflected. Each run was executed for 32 min as a sequence of eight 4-min time periods. Sperry Systems Management validated the model, reporting results on a link-by-link basis for each of the eight time periods (1). The field measurement of networkwide average speed over the 32-min morning peak period was 9.71 miles/h compared with a model estimate of 10.29 miles/h. For the off-peak period, the model estimated an 8.79-mile/h average speed, which compared very favorably with an observed speed of 8.73 miles/h.

PROGRAM EFFICIENCY

The Level II model was executed on a CDC 7600 computer at the Brookhaven National Laboratory in Upton, New York. Computer time for the model depends strongly on the size of the network. Runs of the validation network of 96 links indicate a ratio of simulated time to computer time of approximately 160:1 and a cost of less than $8 for a 32-min simulation and "fill" time of 6 min. The computer memory requirement is reasonable. For IBM computers, less than 250 K bytes are required; on CDC machines, less than 40 K words are needed.

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TRAFLO: A New Tool to Evaluate Transportation System Management Strategies

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The TRAFLO model, which combines the attributes of traffic simulation with traffic assignment, is described. TRAFLO was developed as a tool for use in transportation planning and traffic engineering to test transportation management strategies. It is a software system, programmed in FORTRAN, that consists of five component models that interface with one another to form an integrated system. Four of the models simulate traffic operations, and the fifth is an equilibrium traffic assignment model. The operating characteristics of the component simulation models are described. These models are capable of simulating traffic on one or more of the following networks: freeways, corridors that include the freeway/ramp/service-road complex, urban and suburban arterials, and grid networks representing the central business districts of urban centers. Also described is the traffic assignment component, which can be used in conjunction with the simulation components to determine the response of a traffic system to a transportation management strategy.

In recent years, events have shifted attention to the need for providing safe, efficient, and economical movement of people and goods on existing highway facilities. Furthermore, there is a growing awareness that factors such as air and noise pollution and the conservation of energy must be weighted heavily in any decision process involving the nation's transportation system.

These considerations have led to the emergence of transportation management as the basis for improving the mobility of people and goods. The application of the transportation management process requires the ability to quantitatively assess alternative transportation management strategies to identify those that best satisfy the stated objectives.

The scope of the process involves both the transportation planning and traffic engineering disciplines. The involvement of these two disciplines reflects the intrinsic dependence of behavioral responses (trip generation, distribution, and assignment and modal choice) on the performance of the transportation system as expressed in terms of travel time, cost, and accessibility.

It is clear that the need to develop effective transportation management strategies implies a requirement to develop analytic tools for that purpose. Furthermore, these tools must be sufficiently broad in scope to meet the objectives of the transportation management process for both disciplines identified above.

One tool that is particularly effective for evaluating transportation management strategies applied to a dynamic environment is traffic simulation. Simulation models provide the means for evaluating a wide spectrum of traffic management schemes within the framework of a controlled