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This paper is based on research conducted as part of an interagency project entitled "Southwest Freeway Improvement Evaluations" sponsored by the Texas State Department of Highways and Public Transportation. The views, interpretations, and conclusions expressed are those of the authors. They are not necessarily those of the Texas State Department of Highways and Public Transportation.

Publication of this paper sponsored by Committee on Traffic Flow Theory and Characteristics.

Development and Application of a Macroscopic Model for Rural Highways

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ABSTRACT

The development of a macroscopic computer simulation model is presented. The simulation model, RURAL1, calculates traffic performance given road supply (geometrics) and demand (traffic) information. The model can analyze four types of subsections: freeway, multilane, two-lane, and passing-lane. To perform the simulation, the roadway must first be divided into subsections; users can specify up to 100 subsections. Subsection boundaries are established on the basis of changes in road geometrics, or traffic demand characteristics, or both. RURAL1 calculates traffic performance measures, such as average speed, travel time, and vehicle delay, on a directional basis for each subsection and summarizes performance results for the entire roadway section. The simulation model was applied to an actual field site where the existing condition was evaluated against two additional cases.

In recent years road maintenance budgets have increased substantially, affecting the availability of funding for new construction. Thus, state transportation agencies have been looking for new ways of managing the existing transportation system more effectively, using an approach called transportation system management (TSM). This approach is now being applied to the rural road system.

New techniques are needed to evaluate the cost-effectiveness of rural road improvements and to provide planners and decision makers with more accurate information on which to base their decisions. Sophisticated computer models, all microscopic, have been developed to study traffic operations on rural roads. Although these models offer great capabilities for analyzing traffic behavior, their applications are limited. Particularly important is the restriction these models impose on the size of the road section that can be simulated. Because of their simpler structure and logic, macroscopic models can easily be used to study longer sections of roadway where several improvements are to be implemented. However, as a result of their simplified logic, macroscopic models offer less detail and precision in performance and measures of effectiveness (MOEs) than microscopic models do and should be treated as a supplement to microscopic models rather than as a replacement.

Historically, macroscopic models have been derived after the development of, and with the use of, microscopic models. In freeway corridors, for example, the development of the macroscopic FREQ model followed early microscopic models used in the analysis and study of freeway operations. The need to consider additional impacts and to study more control strategies played an important role in the creation of FREQ. Another example is TRANSYT, a macroscopic model for the analysis and optimization of a coordinated set of intersections. TRANSYT followed earlier microscopic models for the study of isolated intersections. The complexity of the system (a group of intersections) and additional impacts such as fuel consumption and emissions were the primary reasons for the creation of TRANSYT. As a system grows in complexity (long sections with many geometric elements) and as the study of more impacts is required, macroscopic models will be employed because of the relative simplicity with which they handle more complicated situations.

A study, sponsored by the California Department of Transportation (Caltrans) and FHWA, is being conducted at the University of California, Berkeley, to develop a macroscopic model for the analysis of traffic operations on rural roads. The development and initial application of RURAL1, the first version of this model, are described herein.

BACKGROUND

Since 1976 a series of traffic simulation models has been developed at the Institute of Transportation Studies (ITS) at the University of California, Berkeley, to assist in the evaluation of traffic performance on rural highways. SIMTOL, the first of these models, was developed by W.A. Stock (1) for two-lane, two-way rural roads. Allowing for detailed modeling of vertical alignment data, SIMTOL assumed a high standard horizontal alignment that did not affect driver behavior, except with respect to no-passing zones. The major drawback of the model was that it simulated one direction of traffic, making assumptions about the gaps in the opposite flow. Despite this limitation, the model provided interesting information on the spatial characteristics of two-lane traffic.

In 1980 Botha and May (2) developed a computer program (TWOMIC2-CL) for the microscopic simulation of traffic operations on rural roads with climbing lanes. This model was a modification of a sophisticated simulation model for two-lane, two-way rural roads developed at the Midwest Research Institute--the TWOWAF model, which has been thoroughly validated and used by many research organizations across the United States. Botha and May incorporated the capability of simulating climbing-lane operations in the TWOWAF model's logic. TWOMIC2-CL was then used to derive guidelines for the optimal length and location of a climbing lane on a specific grade. Improvements of TWOMIC2-CL, which were identified by Botha, were undertaken in a follow-up research project.

A recently completed research project (3) produced an improved version of TWOMIC2-CL. The new model, TWOMIC3-CL, has revamped merging logic and additional input and output refinements; it also introduces a new measure of effectiveness (MOE)--accident potential. TWOMIC3-CL needs additional validation of the maneuver multipliers used in the derivation of the accident potential MOE. One aspect of this research was the development of an approach to the construction of a macroscopic model.

Recent simulation models have been developed elsewhere. First, the North Carolina State University (NCSU) model (4) was derived from an earlier simulation model developed by the Franklin Research Institute (the FIRL model) (5). The NCSU model incorporated a detailed truck-passing performance model and a routine to generate speed and headway data points, individual travel times, and so forth. The NCSU model was later modified to simulate roadway intersections (6).

Second, the Swedish National Road and Traffic Research Institute developed an event-based simulation model for rural highways, the Swedish-VTI model (7). This model, written in SIMULA-67, is probably one of the most thoroughly validated two-lane simulation models currently available. Several classes of vehicles can be specified with stochastically selected desired speeds. The model has a comprehensive passing logic derived from empirical passing observation studies conducted in Sweden. The model has been used by the National Swedish Road Board to investigate improvement options on primary roads and is now being adapted for use in several countries, including the United Kingdom and India.

Third, St. John and Kobett developed a microscopic simulation model, known as the TWOWAF model (8), which is able to simulate two-way traffic operations on two-lane highways for a wide variety of configurations. The model can simulate several vehicle classes; passing maneuvers and vehicle performance are also simulated in great detail. Some refinements made to the TWOWAF model are improved vehicle generation routines, reduced number of vehicle classes, and program redimensioning. A group of researchers at the Texas Transportation Institute, headed by Carroll Messer in cooperation with KLD Associates (9), have used a slightly modified version of the TWOWAF model in deriving the relationships for the two-lane chapter of the new Highway Capacity Manual (HCM) (10).

Finally, two simulation models have been developed in Australia. The first model was developed by the Australian Road Research Board (ARRB) and it is called the TRARR model (11). It has the flexibility to specify up to 18 vehicle classes. Its passing logic is based on a set of deterministic decision rules and passing safety values. The TRARR model requires an extensive input data file of road characteristics and traffic parameters. ARRB staff are calibrating the TRARR model in conjunction with case study applications. The second Australian model was developed by Hoban (12) and consists of a set of programs based on the results of previous studies of traffic behavior and simulation. The model was used to investigate the effect of passing lanes on the traffic performance of rural roads and was deliberately restricted to fairly level terrain and uncongested flow rates.

Most of the research conducted at ITS and elsewhere has been concerned with the development of microscopic simulation models; apparently, there have been no macroscopic models available for evaluating traffic performance on rural highways. Because of the limitations of existing microscopic models, it was believed that a simulation model capable of studying traffic operations over long stretches of roadway was needed, and the idea of developing a macroscopic model, RURAL1, was generated.

RURAL1

RURAL1 is a macroscopic deterministic model for the analysis of traffic on rural roads. The structure of the rural highway model is rather simple. Given supply information (road geometrics and subsection breakdown) and demand information (traffic characteristics), RURAL1 calculates performance and relevant MOEs. Subsection boundaries should be established any time there are changes in supply or demand characteristics; for example, changes in gradient or design speed are considered in the criteria for subsection specification, and an intersection is treated as a boundary condition because traffic volumes change at this location. Each of the four submodels comprising RURAL1 analyzes a corresponding subsection type; these submodels are shown in Figure 1. A fifth submodel dealing with subsection dependency is also shown in Figure 1. The submodels are processed independently; RURAL1 uses them when it encounters the particular type of subsection analyzed by each submodel. The submodels can be used several times during a single run, depending on the number of subsections of a specific type.

This simplified model structure allows (a) ease of constructing and programming the model; (b) flexibility for change and incorporation of program submodels; and (c) a short amount of computer time expended in a single simulation, which allows the user to evaluate many alternatives at a low cost. The five submodels are described hereafter.

Freeway Analysis Submodel

This submodel evaluates capacity and performance for freeway subsections on a directional basis. The calculations are based on the principles of the draft report on capacity and level of service evaluation for basic freeway segments (13). The submodel first calculates subsection capacity using Equation 1, which includes a driver factor (which accounts for a driver's knowledge of the road) and truck mix, grade and grade length, lane width, and other factors.

$$C = c_i \cdot N \cdot f_w \cdot f_{hv} \cdot f_t \quad (1)$$

where

C = capacity in vehicles per hour (vph) one way;

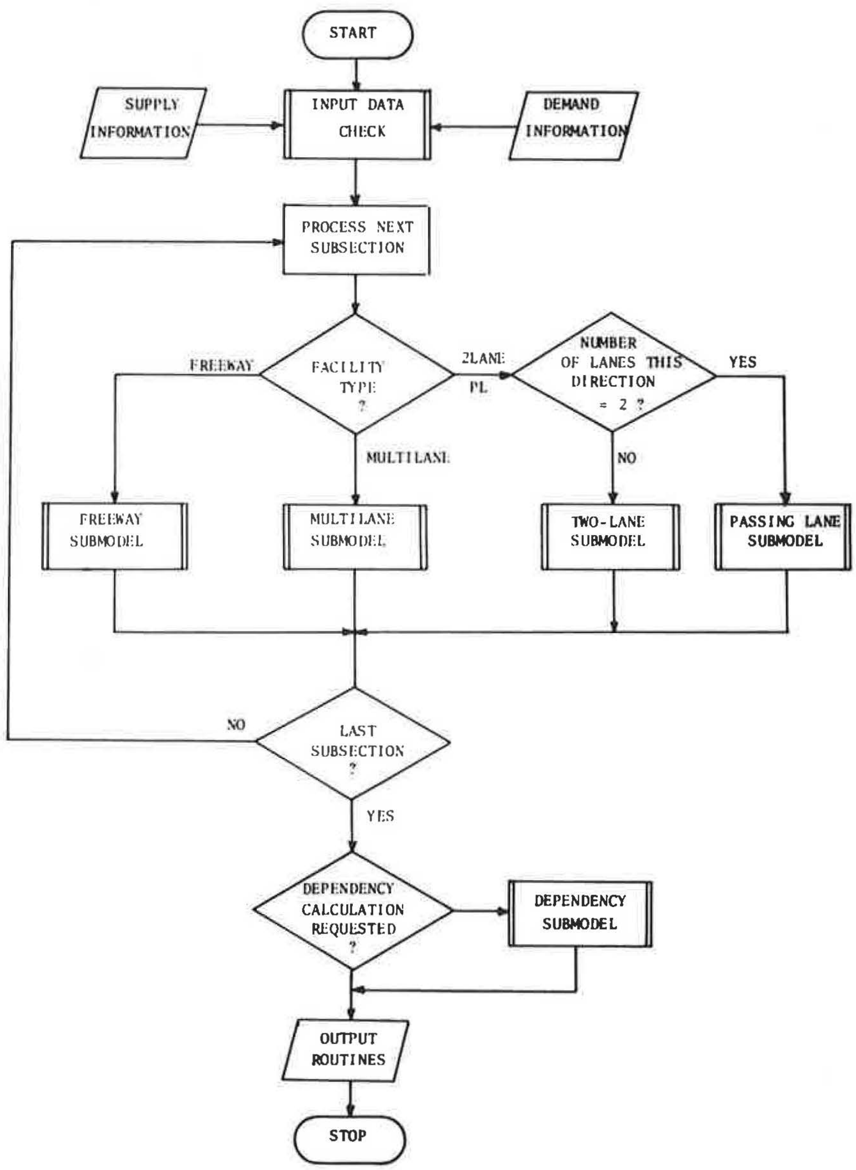

FIGURE 1 Schematic representation of RURAL1 with program submodels.

c_i = capacity under ideal conditions in passenger cars per hour per lane (pcphpl);
N = number of lanes in one direction;
f_w = lane and shoulder width factor;
f_{hv} = heavy vehicle factor; and
f_t = driver population factor.

After capacity is calculated, the submodel calculates subsection volume-to-capacity (V/C) ratio using volume adjusted by peak-hour factor as shown in Equation 2.

$$V/C = (V/PHF) \cdot (1/C) \quad (2)$$

where V/C is the volume-to-capacity ratio, V is the actual one-way volume in vph, PHF is the peak-hour factor, and C is as defined previously.

When the V/C has been computed, MOEs are calculated using the V/C, speed, and density relationships presented in the draft freeway chapter of the new Highway Capacity Manual. Downgrade analysis is performed in a similar fashion but with modified truck equivalent values related to the steepness of the downgrade.

Multilane Analysis Submodel

Like the freeway submodel, the multilane submodel calculates capacity and performance for multilane subsections on a directional basis. It makes use of the principles of the draft report for capacity and level of service evaluation for multilane subsections (14). The freeway submodel and multilane submodel are similar. Major differences in multilane analysis are the introduction of a divider factor to account for the type of median divider available and different factors for lane width and side obstructions based on the median divider type. Equations 3 and 4 show the multilane analysis.

$$C = c_i \cdot N \cdot f_{hv} \cdot f_w \cdot f_{te} \cdot f_t \quad (3)$$

$$V/C = (V/PHF) \cdot (1/C) \quad (4)$$

where f_{te} is a factor for type of multilane highway and c, c_i, N, f_w, f_{hv}, f_t, V, V/C, and PHF are as in Equations 1 and 2.

Two-Lane Analysis Submodel

Based on the capacity and level of service procedures developed in the draft report for two-lane highways (9) the two-lane submodel uses the specific grade approach proposed in this draft report. The calculations required to determine traffic performance are different from those of the other two submodels. Instead of calculating capacity and obtaining a V/C value, the two-lane submodel iterates, beginning with level of service A, until the corresponding level of service is found by comparing actual volume to calculated maximum service volumes. Equation 5 shows the calculation of service volumes for a given level of service.

$$SV_L = 2{,}800 \cdot D_D \cdot H_L \cdot W_L \cdot G_L \cdot A_L \cdot T_L \quad (5)$$

where

SV = service volume at a given level of service (LOS), L, in passenger cars per hour (pcph) two ways;
2,800 = ideal capacity in pcph (two way);
D_D = directional distribution factor;
H_L = peak-hour factor, LOS L;
W_L = lane-width factor, LOS L;
G_L = terrain factor, LOS L;
A_L = passenger car factor (upgrade), LOS L; and
T_L = truck factor, LOS L.

When level of service has been determined, MOEs are calculated using an approach similar to that of the other two submodels: linear interpolation using service volumes rather than V/C values to calculate average speed and other MOEs. Downgrade analysis is performed using the same methodology used for the upgrade but with modified truck equivalent values according to the steepness of the grade.

Passing-Lane Analysis Submodel

This submodel calculates traffic performance for three-lane sections. Figure 2 shows a flow chart of this submodel. Traffic performance for the direction that has the passing lane is calculated using the equations and factors of the multilane submodel with a reduced value for ideal capacity per lane. The basic assumption of the passing-lane submodel is that lane distribution is a function of traffic volume and that heavy vehicles [trucks and recreational vehicles (RVs)] have a tendency to occupy the right lane. Adjusted truck and RV percentages are calculated for each lane and corresponding MOEs

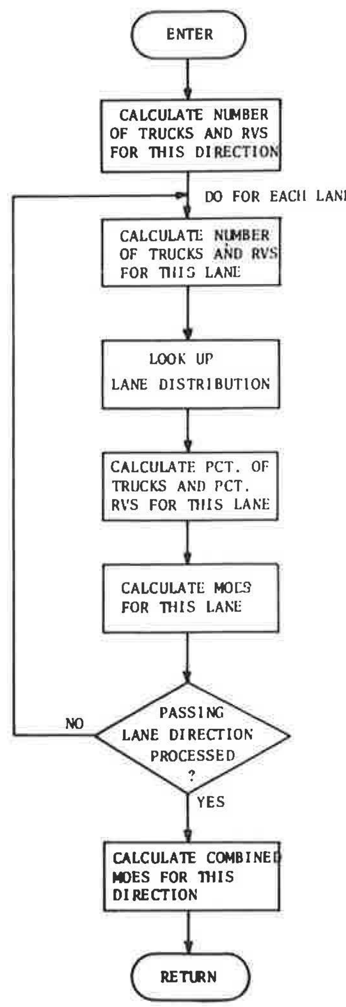

FIGURE 2 Passing-lane submodel.

are also calculated separately and are later combined for the passing-lane direction. Passing lanes longer than 2 miles are calculated as multilane sections and traffic performance for the downgrade direction is calculated as a single direction of a two-lane section with 100 percent restricted passing.

Subsection Dependency Submodel

The main idea of this submodel is to adjust the performance calculations on the basis of the interrelations between adjacent subsections. Traffic performance for any subsection is a function not only of subsection geometric characteristics and traffic volumes; it also depends on the platooning of vehicles in the preceding roadway sections. For example, if a flat subsection is preceded by a steep upgrade, the traffic performance on the flat section will be different than that on the same flat subsection if it were preceded by a downgrade subsection. The subsection dependency submodel tries to quantify the effect of upstream subsections on the subsection being calculated. Figure 3 shows the submodel's logic. The dependency submodel is perhaps the most critical component of RURAL1 and efforts are being made to calibrate it successfully.

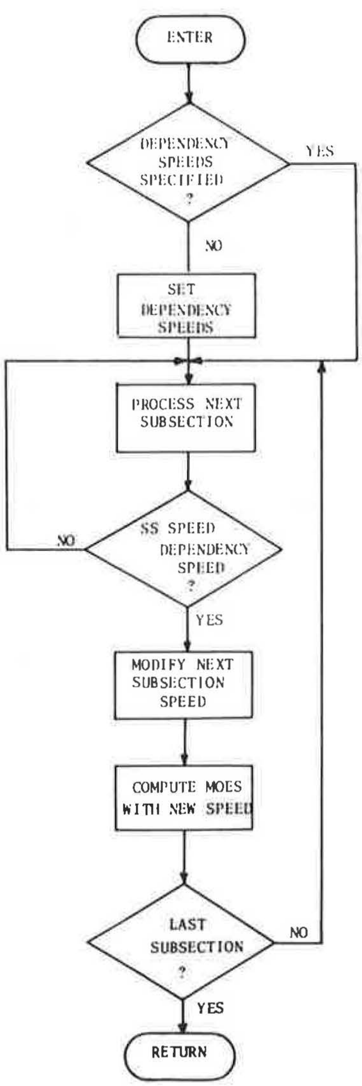

FIGURE 3 Subsection dependency submodel.

Model Assumptions

RURAL1 is a macroscopic deterministic model; thus the behavior of individual vehicles is ignored in favor of the average behavior of platoons or groups of vehicles. No special allowance is made for the actual randomness of demand input parameters. This may appear to be a considerable simplification of real life, but the comparative simplicity (relative to a microscopic model) affords a rapid cost-effective way of obtaining reasonable estimates of the performance of many design configurations.

The assumptions of RURAL1 can be categorized as general or specific. General assumptions hold for the entire section of roadway and are related to the program logic. Specific assumptions are those that relate to the specific type of subsection analyzed or the type of calculation performed.

General Assumptions

General assumptions of RURAL1 are

1. Calculations are made for a 1-hr time slice; demand remains constant within this time period.
2. The program deals only with uncongested flow; demand cannot exceed capacity.
3. The road is broken into subsections and subsection performance is calculated independently. The subsection dependency submodel will correct this deficiency.
4. The program evaluates performance only for a given demand and supply configuration.
5. The program uses the principles of the draft reports on capacity and level of service evaluation for freeway, multilane, and two-lane sections.
6. Four types of subsections can be analyzed: freeway, multilane, two-lane, and passing lane (F, M, 2L, PL).

Specific Assumptions

Specific assumptions of RURAL1 are

1. A typical truck table [200 lb/nominal horsepower (NHP)] is used in calculating passenger car equivalents (F, M, 2L, PL).
2. The gradient for the second direction is assumed to have the same magnitude as the first direction but reverse sign (F, M, 2L, PL).
3. Horizontal curvature is taken into consideration in the specification of no-passing zones (2L).
4. Linear interpolation is used to determine the level of service and corresponding MOEs (F, M, 2L, PL).
5. Performance calculations are conducted separately for each direction (F, M, 2L, PL).
6. Downgrade treatment is done using the modified truck equivalent values according to the steepness of the grade (F, M, 2L, PL).

Input Data Description

Input data are divided into two categories: common input and subsection input. Common input data are the relevant information that remains unchanged for the entire road section or for a particular type of subsection. Subsection input data, the information pertinent to a particular road subsection, are divided into geometric and traffic data and can be specified for both directions or only one direction.

Common Input Data

Common input data are specified in the first card of the input deck. The fields are

1. Problem description: a 60-character alphanumeric field describing the simulation run.
2. Number of subsections: the total number of subsections into which the road section has been divided. A maximum of 100 subsections can be specified.
3. Calculation type: the type of calculation RURAL1 will conduct. Three types of calculations can be specified: performance, demand, and supply. RURAL1 can handle only type 1 calculation (i.e., it can only calculate performance at the present time).
4. Main direction specification: cardinal orientation used only for identification. (RURAL1 assumes that direction 1 is the main direction.)
5. Desired speed: the speed at which a motorist would drive the entire road if not restricted by geometrics or traffic. This value is used in the calculation of vehicle delay.
6. Driver factor: used in the performance calculations for freeway and multilane sections. It will remain constant for all freeway and multilane sections.
7. Output level: can take a value of 0 for a summary output (default) or 1 for a detailed output (see next section for output description).

Subsection Input Data

Subsection input data require a card for each of the road subsections and include information for both directions. Data are divided into geometric data and traffic data. Geometric data refer to the physical attributes of the road subsection, and traffic data refer to the characteristics of traffic for each subsection. Geometric data and traffic data can be specified for both directions or for one direction if constant.

Geometric Data

Geometric data include

1. Subsection type: type 1, 2, or 3, corresponding respectively to freeway, multilane, or two-lane section. If the section is type 2, multilane, it should be specified whether the subsection is divided. The numbers 2-0 correspond to undivided multilane and 2-1 to divided multilane sections. Passing-lane sections should be coded as type 3.
2. Number of lanes: the number of subsection lanes per direction.
3. Percent grade: gradient for direction 1; program automatically reverses the sign for direction 2.
4. Subsection length: the length in hundredths of a mile of a particular subsection.
5. Design speed: the subsection design speed expressed in mph; specified for all four types of subsections. The freeway and multilane submodels use the design speed in the interpolation of V/C, and the two-lane submodel uses it through the specification of no-passing zones.
6. Lane width: subsection lane width in feet; assumed constant for both directions.
7. Obstruction distance: median and side obstruction for freeway and multilane sections and side obstruction for two-lane and passing-lane sections, expressed in feet.
8. Percent no-passing zones: specified for both directions; only relevant for two-lane sections. The single lane of a passing-lane subsection is assumed to have 100 percent restricted passing. Field should be left blank for freeway and multilane sections.

Traffic Data

Traffic data include

1. Level of service: should be left blank because RURAL1 calculates performance only.
2. Traffic volume: expressed as two-way hourly volume.
3. Directional split: percent of two-way traffic traveling in direction 1; used in calculating directional volumes.
4. Percent trucks: percent of single-unit and tractor-trailer combinations with six or more tires on the pavement excluding recreational vehicles; specified for each direction.
5. Percent recreational vehicles: percent of vehicles having six or more tires not included in earlier classification; specified for each direction.
6. Peak-hour factor: defined as the rate of the peak-hour volume to the maximum flow rate for a specified period, usually 15 min, within the peak hour; specified for each direction; field can be left blank for two-lane sections and program will select default value.

Output Description

RURAL1 presents two output options that are selected in one of the fields of the first input card. A value of 0 in this field specifies that the user would like a summary output. A value of 1 indicates a request for a detailed output.

The summary output option provides the user with a replication of the input deck that can be used to check the values of the different fields. If one of the field values is out of range, RURAL1 will not process the information and will underline the corresponding wrong field. The second part of the summary output provides a direction summary of the calculations performed by RURAL1. Some geometric and traffic features are given in this summary along with the MOE calculations. In addition, a direction total with average and maximum values for some MOEs is printed. Finally, a table is provided showing the simulation results for each direction and the totals for both directions.

The detailed output consists of the summary output plus a detailed subsection output with the factors calculated by the program for each subsection. One page is used to show both directions for any road subsection.

Use of the Model

RURAL1 can be used in many ways to evaluate traffic performance on rural roads. A first application of RURAL1 is the study of traffic behavior along a road section with variable geometric characteristics for a given hourly traffic volume. A single run must be made with road subsection specifications that include road and traffic characteristics.

A before-and-after study could be conducted using RURAL1 to evaluate changes in traffic performance resulting from different design strategies. Several design alternatives can be evaluated by comparing them with each other or with the no-action alternative. The number of simulation runs depends on the number of design alternatives to be studied.

Another possible application of RURAL1 is the evaluation of traffic performance on the same road section over a predetermined time period when traffic demand varies. Two simulation runs must be conducted: one with the road geometrics and the base traffic characteristics as input data, and the other with unchanged road features and the new data on traffic characteristics. Users could find RURAL1 helpful in the prediction of traffic performance on a road section where no actions are taken over fixed time intervals (e.g., 5-year, 10-year intervals). Using the detailed output option, RURAL1 can evaluate several road sections that are not connected. If the model is used this way, performance summary tables should be ignored.

RURAL1 has been derived using the preliminary draft information on capacity and level of service evaluation for freeway, multilane, and two-lane sections; to date, it is the only computerized method for using these draft procedures. One possible application of RURAL1 is the evaluation of the relationships proposed in these capacity procedures. It is important to mention that RURAL1 has been constructed in a modular fashion that makes future changes to these procedures easy to handle.

MODEL APPLICATION

A practical application of RURAL1 to a case study is presented here to evaluate the effects of changes in geometric and traffic characteristics on two-lane roads. Three of the model uses described before are demonstrated in this application: road section evaluation, demand change evaluation, and design change evaluation.

Site Selection

A rural highway section was selected from several candidate locations meeting the selection criteria. Table 1 gives a list of rural highway sections in California that were considered. After further investigation of these sites, including field visits in some cases, a 54-mile-long section on CA-20 in Lake and Colusa counties was selected. Adequate information on both geometric and traffic characteristics is available for this site. Figure 4 shows a map of the study section with major highways that connect to it or are nearby.

Data Collection

RURAL1 requires geometric and traffic data to calculate road section performance. Geometric data were reduced from available road plans between post miles

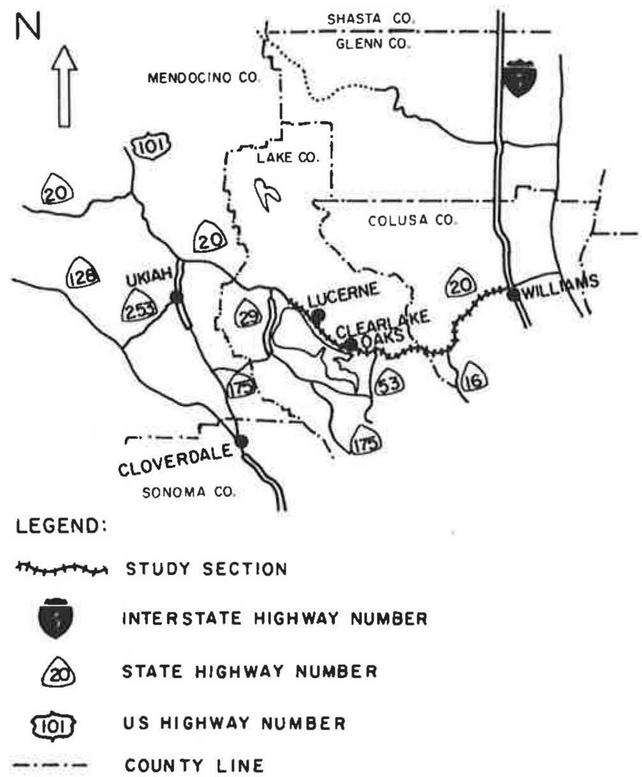

FIGURE 4 Map showing study section.

TABLE 1 Candidate Locations for Initial Model Application

ROUTE	COUNTY	DISTRICT	LENGTH (MILES)	CL	ADT[a]	PERCENT[a] TRUCKS	TERRAIN[b]
20	LAK/COL	01/03	54	YES	8,900	6.8-14.2	R-M
41	MAD	06	46	YES	11,600	6.2-11.7	F-R-M
44	SHA	02	55	YES	2,800	6.6-24.1	F-R-M
70	PLU	02	100	YES	8,300	2.3-19.4	F-R-M
108	TUO	10	59.5	YES	9,300	3.5-6.0	R-M
128	MEN	01	30	NO	4,050	9.0-15.5	R-M
178	KER	09	80.4	YES	5,200	1.7-21.7	M
299	TRI	01/02	72.3	YES	5,800	3.8-22.9	M

a - 1981 FIGURES

b - TERRAIN: F = FLAT

R = ROLLING

M = MOUNTAINOUS

23 and 46 of Lake County. Road plan information was used to determine horizontal curvature, profile data, and lane-width data. No-passing zone data were determined from the state highway photolog. Because no road plans were available for post miles 10 through 23 in Lake County and post miles 0 through 18 in Colusa County, geometric information was approximated using the data given in the Caltrans Route Segment Report (15) for this route. One simplification, the elimination of passing lanes, had to be made to apply RURAL1 to this section; initially RURAL1 could not handle this type of subsection. To illustrate the model application, the basic section was considered as a two-lane section throughout its entire length.

Traffic data were taken from Caltrans 1981 traffic volume and truck volume reports (16,17). Traffic volumes were adjusted to 1983 and 1988 figures using a 4 percent growth factor, and truck data were assumed to be constant for the same period of time. Because of a lack of recreational vehicles and directional distribution percentages, these values were approximated.

Design of Simulation Experiment

The application of the model was designed to demonstrate three possible uses of RURAL1 for a practical case study: the evaluation of a road section under existing traffic conditions, the evaluation of the same section under changes in traffic demand, and the evaluation of the incorporation of design improvements. Table 2 gives the road configuration for these experiments.

Example 1 in Table 2 gives the road configuration for the first application. The 54-mile road section was divided into 31 homogeneous subsections (SS), with criteria for section division being changes in either demand or supply characteristics. Subsection lengths and percent grade are also shown. Traffic volume corresponds to adjusted 1983 values using a 4 percent annual growth rate. The second simulation run was made with the same roadway configuration used in example 1 because no geometric changes were specified. Traffic volumes were adjusted to 1988 values using the 4 percent growth rate.

Finally, example 2 in Table 2 gives the road configuration including some design improvements in the study section. Subsections 12 and 13 were replaced with two undivided multilane subsections, subsections 14 through 16 were replaced with three divided multilane subsections, and subsections 28 through 31 were replaced with four freeway subsections. Traffic volumes used in this simulation run correspond to adjusted 1988 values.

Simulation Results

Table 3 gives a comparison of the results of the three simulation runs. The first line corresponds to simulation 1, road section evaluation under existing traffic conditions; the second line corresponds to simulation 2, evaluation of a road section with changes in traffic demand for a 5-year period; and the third line corresponds to simulation 3, evaluation of design improvements.

Results shown for each of the simulation runs include average speed, maximum V/C ratio, vehicle travel time, vehicle delay, vehicle-traveled hours and vehicle-traveled miles. Results are presented separately for each direction and totals are given for both directions. Vehicle delay was calculated any time average vehicle speed fell below the user-

TABLE 2 Road Section Configuration for Simulation Experiment

SS #	LENGTH (MILES)	PERCENT GRADE	EXAMPLE 1 BASIC CASE SS. TYPE	EXAMPLE 2 DESIGN CHANGE SS. TYPE
1	3.00	+1.0	2LANE	2LANE
2	4.00	-1.0	2LANE	2LANE
3	3.00	-1.5	2LANE	2LANE
4	3.00	+2.0	2LANE	2LANE
5	2.00	+0.8	2LANE	2LANE
6	1.00	+1.2	2LANE	2LANE
7	1.00	+2.0	2LANE	2LANE
8	1.10	+0.3	2LANE	2LANE
9	1.75	+1.1	2LANE	2LANE
10	0.48	+6.0	2LANE	2LANE
11	1.20	+2.0	2LANE	2LANE
12	1.20	+7.0	2LANE	4LANE DIVIDED
13	1.00	-5.4	2LANE	4LANE DIVIDED
14	0.40	-2.5	2LANE	4LANE UNDIV.
15	0.90	-6.0	2LANE	4LANE UNDIV.
16	1.70	-0.4	2LANE	4LANE UNDIV.
17	2.40	+1.8	2LANE	2LANE
18	0.60	+4.9	2LANE	2LANE
19	1.00	+2.9	2LANE	2LANE
20	1.00	+5.7	2LANE	2LANE
21	1.00	-2.3	2LANE	2LANE
22	1.00	+5.3	2LANE	2LANE
23	1.00	+4.9	2LANE	2LANE
24	1.10	+2.2	2LANE	2LANE
25	0.40	+5.8	2LANE	2LANE
26	1.30	-5.0	2LANE	2LANE
27	2.00	-4.0	2LANE	2LANE
28	3.00	-3.0	2LANE	4LANE FREEWAY
29	4.00	-2.0	2LANE	4LANE FREEWAY
30	3.60	+2.0	2LANE	4LANE FREEWAY
31	4.00	-1.0	2LANE	4LANE FREEWAY

specified desired speed. Delay was computed as the difference in travel times between these speeds times the amount of traffic traveling the section.

Because the volumes are different, the first two simulation runs can be compared only on the basis of average speed and travel time. There are slight changes in average speed and travel time. Run 1 has a higher average speed and lower travel time than run 2.

Simulation runs 2 and 3 can be compared on the basis of total delay and total traveled hours because traffic volumes are the same. Run 3, which includes the design modifications, shows an improvement in overall average speed of 53 mph compared to 51 mph in run 2. Vehicle delay is reduced by 13.8 veh-hr, a 16 percent change from the delay value calculated in run 2. Total traveled hours are reduced by 28 veh-hr, a 3 percent change from the calculated value in simulation 2. It can be concluded from this analysis that design modifications resulted in a modest improvement in traffic operations for the study section.

PROGRAM LIMITATIONS

Limitations of RURAL1 include

1. RURAL1 can handle up to 100 subsections. The program was designed to simulate at least a 50-mile road section.

TABLE 3 Simulation Results

SIMULATION #	DESCRIPTION	DIRECTION	AVERAGE SPEED (MPH)	MAXIMUM V/C	TRAVEL TIME (HR:MIN)	VEHICLE DELAY (VEH-HRS)	TOTAL TRAVELED (VEH-HRS)	TOTAL TRAVELED (VEH-MILE)
1	ROAD SECTION EVALUATION	DIR. 1	52	0.73	1:3	31.2	432	22000
		DIR. 2	51	0.74	1:3	22.0	321	16431
		BOTH	52	0.74	2:6	53.2	753	38341
2	DEMAND CHANGE EVALUATION	DIR. 1	51	0.84	1:4	49.0	537	26822
		DIR. 2	50	0.84	1:4	34.9	395	19919
		BOTH	51	0.84	2:8	83.9	932	46741
3	DESIGN CHANGE EVALUATION	DIR. 1	53	0.84	1:2	43.3	524	26822
		DIR. 2	53	0.84	1:2	26.8	380	19919
		BOTH	53	0.84	2:4	70.1	904	46741

2. RURAL1 treats each subsection independently without allowing for interactions between adjacent subsections. A new logic is being developed to eliminate this problem.

3. RURAL1 cannot handle oversaturated situations (where demand exceeds capacity). The program has no way of knowing in advance if this situation will arise. If a subsection is indeed oversaturated, the program does not calculate its MOEs and cannot calculate direction summary totals. RURAL1 gives an error message in this case.

4. The program can handle four types of subsections: freeway, multilane, two-lane, and passing-lane. Other subsection types (e.g., intersections, speed-limit zones) cannot be evaluated using RURAL1. An error message is given if other subsections are input to the program.

5. The program cannot determine if input data are correct if data are entered within RURAL1 accepted ranges; however, the program does give error messages for out-of-range data.

6. RURAL1 handles performance calculations only.

7. RURAL1 uses a 1-hr time slice and performance calculations are summarized by hour of operation.

CONCLUSIONS AND RECOMMENDATIONS

RURAL1 is a macroscopic deterministic simulation model that can be used for the evaluation of traffic performance on rural highways. Its very simple logic is based on the capacity and level of service procedures presented in the draft reports for freeway, multilane, and two-lane sections of the new Highway Capacity Manual.

RURAL1 lets users study longer sections of roadway at a lower cost than was possible with earlier microscopic models. However, some detail and precision in the calculations are sacrificed compared with calculations by microscopic models.

It is recommended that further research be conducted to eliminate some of the assumptions and limitations of RURAL1. It is also recommended that field studies be conducted to validate model components.

ACKNOWLEDGMENT

The authors would like to thank Fred Rooney of Caltrans Division of Transportation Operations and Ron Nelson of Caltrans District 3 office in Marysville for their valuable comments and cooperation in data collection and analysis. We also thank Laura Wingerd for her excellent programming work with RURAL1.

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This paper is based on work conducted as part of a Highway Planning and Research (HPR) project sponsored by the California Department of Transportation (Caltrans) and the FHWA. However, the contents of this paper reflect the views of the authors who are responsible for the facts and accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the sponsors. This paper does not constitute a standard, specification, or regulation.

Publication of this paper sponsored by Committee on Traffic Flow Theory and Characteristics.

Capacity, Speed, and Platooning Vehicle Equivalents for Two-Lane Rural Highways

MICHEL VAN AERDE and SAM YAGAR

ABSTRACT

Passenger car equivalents (pce's), derived for purposes of capacity, speed, and platooning analyses, are examined using literature sources and traffic data analyzed for 37 different two-lane rural highway sites in Ontario. Speed pce's for trucks and recreational vehicles were found to be considerably higher than those presently used for most types of standard capacity analyses. Truck pce values were found to be 11.4, 6.1, and 3.8 for the 10th, 50th, and 90th percentile speeds, respectively. Corresponding pce values for recreational vehicles were determined as 3.9, 3.7, and 2.6, and the opposing direction pce was found to be 0.5 for all percentiles. The relative effects of trucks and recreational vehicles, in terms of the creation of platoon followers, were found to be much smaller than the corresponding equivalents for speed. Platoon follower pce's for trucks, recreational vehicles, and opposing direction vehicles were 1.23, 1.23, and 0.06 for low traffic volumes and 1.20, 1.07, and 0.07 for high traffic volumes. Platoon leader pce's were 1.55 for recreational vehicles, and 2.0 and 1.35 for trucks on recreational and commuter routes, respectively.

Volumes of different vehicle types and different directions of travel affect the operational characteristics of two-lane two-way rural highways in different ways and to different extents. The analysis of a nonhomogeneous stream of vehicles is therefore often simplified if the relative effect of each vehicle type can be expressed in terms of passenger car equivalent (pce) units. Passenger car equivalents have been quoted for different vehicle types, terrains, levels of service, and rural and urban settings because they can vary with these factors.

Past and current use of vehicle equivalents for trucks, recreational, and opposing direction vehicles on rural two-lane highways on relatively level terrain is reviewed. Specifically, the current practice and literature on pce's are surveyed and these findings are compared with pce values derived from a comprehensive data collection project in Ontario. Because pce's differ for capacity, speed, and platooning analyses, pce values are examined separately for each of these measures. Some of the reasons for these discrepancies are examined.

CURRENT PRACTICE AND LITERATURE ON PCE VALUES

A variety of pce derivations based on capacity analysis are found in the literature, and others pertain to service volumes, speed reduction, or platooning. Separate literature reviews were carried out for each, and the most relevant and significant of these findings are summarized in this section. A comparison of literature estimates and those found in Ontario is provided at the end of the paper.

Capacity-Based Vehicle Equivalents

Vehicle equivalents have most commonly been used for analyses of capacity and level of service. Capacity-