would be made worse off by changing existing neighborhood traffic patterns.

Technical solutions to neighborhood traffic management problems can be found to make the community as a whole better off. In the case of Chevy Chase Section Four, several feasible solutions were identified. However, all of these solutions had something in common. In the jargon of the economist Lester L. Thurow, each solution had a significant zero-sum element (5). That is, someone had to be made worse off so others could benefit. For this reason, the selection of a recommended course of action becomes a matter of political choice.

ACKNOWLEDGMENT

The work reported here was sponsored by the Federal Highway Administration, the Maryland Department of Transportation, and the Town of Chevy Chase Section Four, Maryland.

REFERENCES

1. The Restraint of the Automobile in American Residential Neighborhoods. U.S. Department of Transportation, May 1978.
2. Six Months Experiment--Berkeley Traffic Management Plan. DeLeuw, Cather and Co., San Francisco, May 1976.
3. W. Marconi. Speed-Control Measures in Residential Areas. Traffic Engineering, March 1977, pp. 28-30.
4. A.R. Turturici. An Evaluation of Speed-Curtailing Bumps. Public Works, Aug. 1975, pp. 73-76.
5. L.C. Thurow. The Zero-Sum Society. Basic Books, Inc., New York, 1980.

Publication of this paper sponsored by Committee on Social, Economic, and Environmental Factors of Transportation.

Assessing Traffic Management Strategies in Residential Neighborhoods

ADOLF D. MAY AND SAID M. EASA

This paper describes the development and application of a dense network-type of model, with emphasis on the assessment of traffic management strategies in a residential neighborhood. The MICRO-ASSIGNMENT model was selected for use in this study after extensive literature review and operational experience. The model input and output were modified and fuel computation added. The model was applied to the College Terrace residential neighborhood area of Palo Alto, California. The no-control base condition and five transportation-system-management-type neighborhood strategies were evaluated. The strategies included interior traffic restraint measures and improvement of surrounding arterials. The selected strategies were compared with the no-control base condition. The assessment was on the basis of comparative flows, travel times, and fuel consumption rates on individual links and vehicle miles, vehicle hours, and fuel consumption for residential and arterial street subsystems. This assessment, supported by extensive literature review, served as the basis for developing initial policy guidelines for traffic management strategies in residential neighborhoods.

In recent years, transportation system management (TSM) has become a viable approach to solving traffic problems in various operating environments--dense networks, freeway corridors, arterial networks, rural highways, and so on. The key objective of TSM is to conserve fiscal resources, energy, environmental quality, and quality of urban life through short-term, low-cost transportation improvements. In order to effectively achieve this objective and predict consequences before implementation, analytical techniques are needed for these various operating environments.

This paper describes a research project that was concerned with the development and application of such an analytical technique for dense networks (1,2). The particular dense network covered in this paper was a residential neighborhood. A companion paper addresses a central-business-district-type of dense network.

LITERATURE REVIEW

A literature search was undertaken to make a survey of existing experience and to identify existing and emerging analytical techniques (3).

The survey of existing experience included identification of the problems encountered in the neighborhood areas, various types of TSM strategies implemented, and measures of effectiveness considered. Special attention was devoted to well-documented case studies.

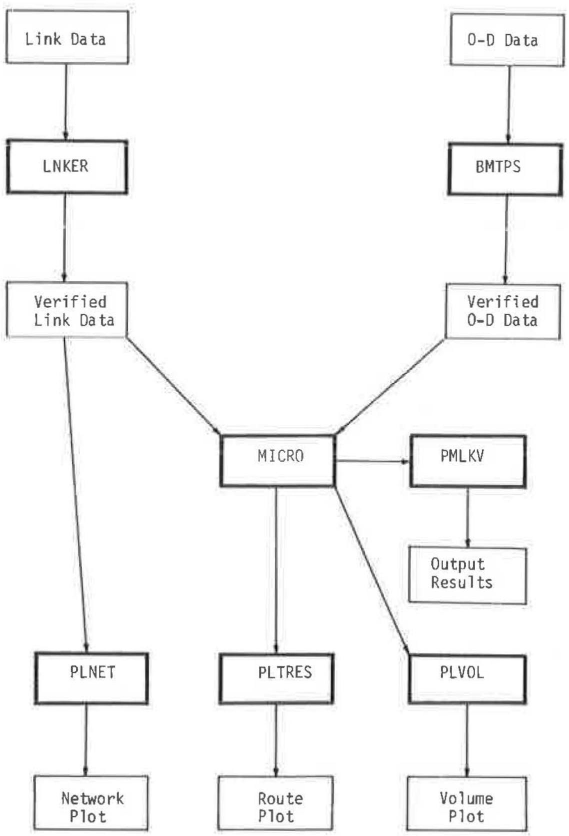
The literature survey also was directed to the identification of analytical techniques tht might be employed to evaluate TSM-type strategies (3). More than 30 such techniques were identified, and six models were evaluated in some detail (4).

MODEL SELECTION

As mentioned in the literature review, 30 models were initially identified (3), and six were selected for in-depth study (4). The six models were CATS (5), CONTRAM (6,7), DHTM (8), MICRO-ASSIGNMENT (9,10), MICRO-UROAD (11,12), and TRANSIGN (13). The six models were evaluated with respect to their input requirements, their method of representing driver behavior and intersection operations, and their history of use and potential for incorporating expanded impact capabilities. Two models, CONTRAM and MICRO-ASSIGNMENT, appeared to be the best-suited for this study. Their nearly offsetting weaknesses and strengths resulted in their both being recommended for use in an actual application to determine which one would be ultimately more suitable for the objectives of this project.

The two models were placed in operation on the IBM system at the California Department of Transportation (Caltrans) and applied simultaneously to the College Terrace residential neighborhood area. The results of these applications provided first-hand information concerning model use-related features. In addition, the theoretical basis of the models and

Figure 1. Component programs of microassignment.



the relative predicted cost of modifications were assessed. The final evaluations of the two models were almost equal, and the final selection hinged on the level of anticipated modification. Since the anticipated modification was relatively minor, the MICRO-ASSIGNMENT model was selected for use in this study (10,14).

MODEL DESCRIPTION AND REFINEMENT

The MICRO-ASSIGNMENT model is capable of assigning traffic to a finely coded street network by various time periods throughout the day. These time periods can range from as short as 6 min to 24-h. Although the model does not simulate queuing conditions resulting when demand exceeds capacity, it does attempt to account for the associated delays in minimum path selection.

The MICRO-ASSIGNMENT model incorporates separate programs that perform different activities related to input data, main program processing, output results, and plotting facilities. The model consists of seven programs as shown in Figure 1. The LNKER program is used to organize and check the supply data, and the BMTPS program performs the same function for the demand data. These data are then input to the main program, MICRO, which performs the traffic assignment procedure, and the results are printed by another separate program, PMLKV. The other three programs (PLNET, PLTRES, and PLVOL) are used, respectively, for plotting the network, the minimum route trees, and the predicted volumes.

The MICRO-ASSIGNMENT model has a number of unique features. For example, nodes are located at mid-block locations (not at intersections), which permit each turning movement to have its own link and simplify turn restrictions and turn-control features. Another important feature is the wide variety of intersection control that can be modeled. Specifically, the model simulates the operation of various types of signalized intersections, as well as non-signalized intersections that include two-way stop signs, four-way stop signs, and yield signs. A key element in the model is the traffic assignment feature. An improved iterative multipath assignment procedure was developed by Caltrans to overcome the disadvantages associated with the sequential assignment method used in the original version (15).

Several alternative refinements were considered and, after careful investigation of their anticipated costs and benefits, three were selected and implemented in the model. The first refinement was adding fuel consumption calculations, which provided information for each link, selected groups of links, and for the total network. The second refinement enables the user to specify in advance grouping of links for which overall impacts are calculated. For example, in the analysis of traffic operations in the College Terrace neighborhood, this feature was used to obtain overall impacts for neighborhood streets, collector distribution streets, and arterials separately. The third refinement was modifying the final calculations and tabulations of output results. One such example was warning messages on links that exhibited poor operational performances such as low fuel-economy rates, low average speeds, and near-capacity lane flows.

The final version of the model is operational on CALTRANS IBM/370 computer and the model, including the modifications, was extensively tested before proceeding with the case study.

CASE STUDY

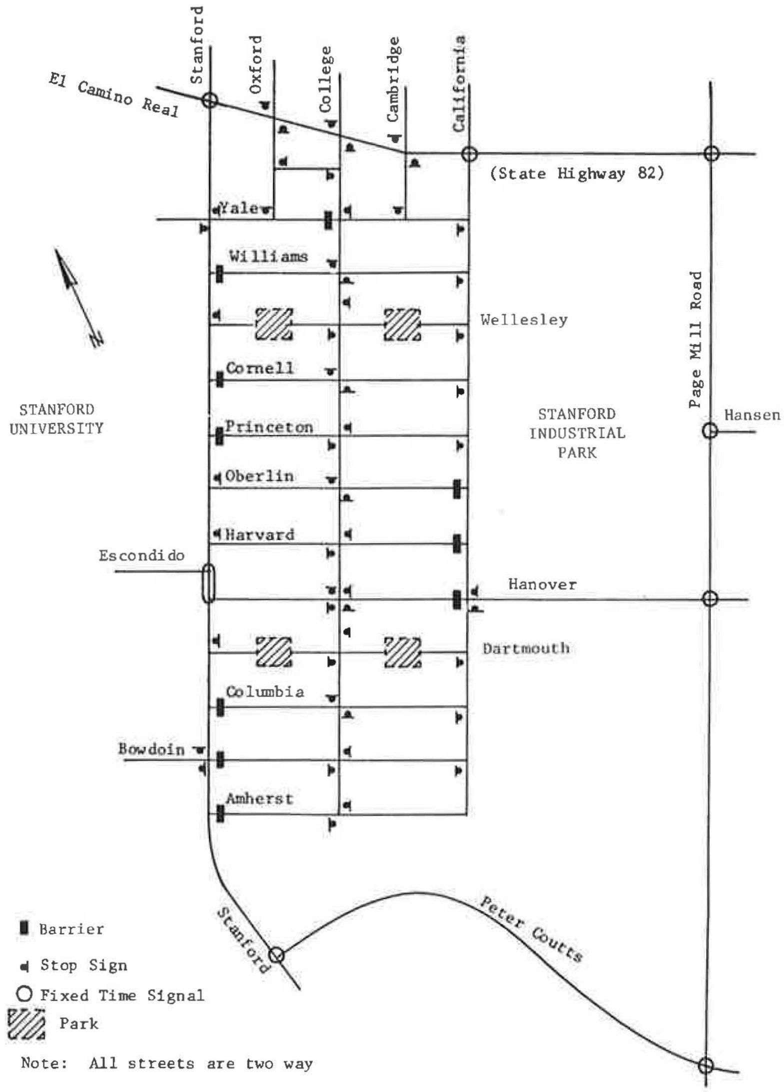
This section is devoted to the application of the MICRO-ASSIGNMENT model to a residential neighborhood area. The residential neighborhood area is the College Terrace neighborhood in Palo Alto, California. The purpose of this exercise is fourfold. First, it can be considered as a user's guide to illustrate the data-collection, model calibration, and model application procedures. Second, the results may have practical significance and be of value to the city of Palo Alto. Third, these real-world applications permit a detailed evaluation of the modified MICRO-ASSIGNMENT model. And, finally, the evaluation of several traffic management schemes provides additional insights toward the establishment of guidelines for traffic management in neighborhoods.

Study Area

The College Terrace study area was selected because of its typical residential area characteristics, the availability of origin-destination (O-D) data, and the excellent cooperation of the city of Palo Alto. A map of the study area is shown in Figure 2. The study area is approximately 1 mile long and 0.6 mile wide; it contains approximately 30 blocks and 50 intersections. The residential area lies between Stanford and California Avenues on the east and west and Yale and Amherst Street on the north and south. Stanford University is located west of Stanford Avenue, and the Stanford Industrial Park is located between California Avenue and Page Mill Road. El Camino Real (CA-82) and Page Mill Road are major arterials, while Stanford, Peter Coutts, and California might be considered collector streets. All other streets are residential streets.

The traffic problem in this neighborhood is primarily due to its location between Stanford University and the Stanford Industrial Park and the fact that over time El Camino Real and Page Mill Road

Figure 2. Study area.



traffic has increased. Eight signalized intersections are in operation along El Camino Real, Page Mill Road, and Stanford Avenue. All other intersections are controlled by stop signs, either for selected approaches or for all approaches.

Four small parks have been constructed (two on Wellesley and two on Dartmouth) to discourage through traffic from penetrating the residential area. Ten full-access control barriers have been constructed to further discourage through traffic. Six such barriers were installed just east of Stanford on Williams, Cornell, Princeton, Columbia, Bowdoin, and Amherst. Three others are located just west of California on Oberlin, Harvard, and Hanover, while the tenth barrier is located on Yale, west of College. This is the control plan that has been in operation since January 1979.

Data Collection

The MICRO-ASSIGNMENT model requires network-related data and O-D demand data. The network-related data were collected for January 1979 in a straightforward manner. The O-D demand data were more complicated because the complete data set was not available and also because the O-D data set had been collected in January 1973 for the neighborhood area only and had to be modified to conform to the large study area and to be projected to January 1979.

The O-D traffic demands used in the evaluation study corresponded to the afternoon peak period (3:00-6:00 p.m.) for January 1979. The demand data were based on a roadside interview survey conducted by the city of Palo Alto in January 1973. The interviews were taken at seven locations that represent the major entry (or exit) points to the area. The survey extended for 10.5 h (7:30 a.m.-6:00 p.m.), and drivers were interviewed as they entered the neighborhood.

Based on these interviews, the O-D traffic demands were established (on an hourly basis) from actual external origins to external destinations and from station-to-station on the neighborhood boundary. The station-to-station demands for the neighborhood were used since the study was particularly concerned with travel within the neighborhood. Two problems were encountered. First, origins (and destinations) within the neighborhood had to be disaggregated. Second, three of the interview stations were within the cordon line of the network and O-D data had to be transformed to artificial origins and destinations on the periphery.

In establishing the origins and destinations within the neighborhood, available information on dwelling unit characteristics was used. Such information included the average trip rate per dwelling unit, the number of dwelling units in each neighborhood block, and dwelling unit classification (single family or multiple family). The average trip rate was estimated as 10 trips per dwelling per day (note that these are one-way trips). Clearly, the estimated average trip rate would only be valid for the 24-h period of the day. In studying the morning or the afternoon periods, the average trip rate would certainly be different and, consequently, the trip-making frequency for neighborhood traffic was required.

With available information on the demands from the interview stations to the neighborhood and the directional volume counts at the interview stations, the trip-making frequency of the neighborhood trips was established at stations 1 and 5. It should be noted that these stations were the only stations at which volume counts and the roadside interviews were conducted on the same day. The trips originating from the area exhibited three peak periods, where the midday peak period is likely due to shopping and other nonpeak trips. For the trips destined for the neighborhood area, a substantial number of these trips occurred between 8:30 and 9:30 a.m. This is attributable to the fact that the trips destined for the neighborhood area include not only those trips to the neighborhood itself, but also those to a portion of the Stanford Industrial Park.

It was estimated that the number of trips originating from the neighborhood during the morning peak period (7:30-10:00 a.m.) was 25 percent of total daily trips produced by the neighborhood. The number of trips destined for the neighborhood during the afternoon peak period (3:00-6:00 p.m.) was estimated to be 40 percent of the total daily trips. These percentages were then applied to the total daily neighborhood trips in order to determine the number of trips originating from, and destined for, the neighborhood during peak periods.

As mentioned previously, some interview stations were located within the study network, and it was necessary to modify the demands corresponding to these stations in order to be compatible with the origins (and destinations) located on the periphery of the study network. Such a modification was required for stations 1, 2, 3, 4, and 5 since the remaining stations were already located on the periphery of the study network.

Establishing the O-D demands was accomplished in two steps. First, the trip demands at the five stations mentioned above were assigned to several O-D nodes on Page Mill, El Camino Real, and Stanford. The disaggregation of trip demands was accomplished by using the information that described the actual trip origins and destinations available from the roadside interview survey. Second, the reader can immediately see that restructuring of the trip demands at the interview stations was not sufficient. This is because other trip demands (mainly through trips) that used the surrounding highways and arterials were not included. Consequently, additional trip demands for El Camino Real, Page Mill Road, and Peter Coutts were fabricated, based on actual traffic volumes on these roads. For example, in order to match the observed volumes on El Camino Real, a demand of 4457 trips in each direction was assigned to that highway for the 3-h peak period. With the above procedure, the process of establishing the O-D demands for the afternoon peak period in January 1973 was completed.

Calibration Process

The O-D demand data available for January 1973 needed to be adjusted so that the predicted traffic was consistent with that measured in January 1979. It was found that a 5 percent overall O-D demand growth rate adjustment on the 1973 data was adequate to represent traffic demands in January 1979. In the following paragraphs, the selection of the growth rate and the comparison between the adjusted traffic and that measured in January 1979 are described.

Two types of O-D demand changes are generally possible: overall demand growth and specific local demand changes due to particular land utility changes. Since there was little local land utility change in the study area during the years from 1973 to 1979, the overall traffic demand growth was the only adjustment considered. Growth rates of 5 percent and 10 percent were tested. The results indicated that the demands obtained by a 5 percent increase from the 1973 data adequately predicted the traffic conditions in January 1979.

Two important measurable traffic operating quantities were used in the comparison of the predicted and the real situation. They were the traffic volume on important links and the travel time along selected streets. The quantities predicted, based on the 5 percent O-D demand increases, are compared with the measured values in the following paragraphs.

The comparison of the predicted and actual values in January 1979 included two measures: traffic volumes and travel times. The actual data were collected by the city of Palo Alto during the afternoon peak period (3:00-6:00 p.m.). Traffic volumes were collected at five intersections and at several midblock locations. In addition, travel time runs were conducted along four selected routes. Below are the results of the comparisons of predicted and actual traffic volumes and travel times.

The traffic-volume counting stations were arranged to emphasize the volume on the peripheral arterials as well as the cross traffic between the residential area and the peripheral streets. The comparison of the measured and predicted volumes indicated that 72 percent of the locations exhibit a difference of less than ±10 percent. For locations with higher volumes, the results were even better. For example, for locations with a volume range of 500 to 100 vehicles/h, 9 out of 12 locations (75 percent) exhibit a difference of less than ±10 percent, and for the 1000-1500 vehicles/h range the difference is less than ±10 percent at all locations.

The travel times along several selected routes were measured as another comparison between the predicted and actual values. The routes include the peripheral arterials in both clockwise and counterclockwise directions, the eastbound and westbound directions along College Avenue, round-trip travel along California Avenue, and the northbound and southbound directions along Hanover Street. These test routes cover the surrounding arterials, the main entrance to the residential area from the peripheries, and transverse streets in the residential area.

The differences were within 5 percent, except for the clockwise direction along the periphery and the eastbound direction along College Avenue. The overall difference was 9 percent.

From the above description, it can be seen that the 5 percent overall increase O-D adjustment matches actual traffic conditions within 10 percent without systematic deviation. Furthermore, the traffic management staff in Palo Alto reviewed the results and agreed, based on their knowledge of local traffic conditions, that the simulation results were acceptable and that TSM strategies could be evaluated, based on these calibrated O-D demands.

Evaluation of Control Plans

After the calibration process was completed, the

Table 1. Control plans selected.

	Additional Action Taken	
Plan	Within Residential Area	On Surrounding Arterials
0	None	None
1	Existing control (10 barriers)	None
2	None	Proposed improvement (El Camino-Page Mill interchange)
3	None	Proposed improvement (Page Mill added lanes)
4	None	Proposed improvements (El Camino-Page Mill interchange and Page Mill added lanes)
5	Proposed control (Hanover barrier)	None

next step was to evaluate the impacts of several control plans. The selection of the College Terrace neighborhood as a study area provided a good standard for analyzing residential areas. The primary purpose of traffic management in this area was to reduce environmental impacts within the residential area while maintaining an acceptable level of traffic operations on the surrounding arterials and neighborhood accessibility. Based on these basic criteria, five control plans were studied and compared with the base conditions (no control).

Description of Control Plans

Five control plans, in addition to the do-nothing alternative, were selected for evaluation. The majority of these plans was proposed by the city of Palo Alto. A list of selected plans is shown in Table 1. For comparison purposes, the do-nothing alternative (no control) was designed as plan 0, and the five selected plans were compared with this plan. The control plan in operation today is designated as plan 1 (see Figure 2). In this plan, all cross streets were closed at one end or the other in order to keep the traffic out of the neighborhood. Plan 2 was to convert the El Camino Real-Page Mill intersection into an interchange that would improve traffic conditions along the El Camino Real and Page Mill Road. Another strategy selected, plan 3, was to add one lane in each direction to Page Mill Road. Plan 4 was a combination of plan 2 and plan 3, and plan 5 was to block Hanover Street each of California Street.

As noted, these plans can be classified into two groups. One group is designed to push the through traffic outside the neighborhood (plans 1 and 5) by restricting the access (or egress) to the area. The other group is designed to pull the through traffic out of the neighborhood (plans 2, 3, and 4) by improving the operations on the surrounding arterials.

Results of Control Plans

To evaluate the impacts of control plans, a separate input of network data was prepared for each plan. The calibrated O-D demand data were not changed, since all plans were evaluated for January 1979 conditions. Separate computer runs were then made for each plan. The number of iterations varied from plan to plan because of the convergence of the traffic assignment results. Both total vehicle hours and total vehicle miles were used as indicators of the convergence.

The impacts of the control plans on both traffic volume and travel time were calculated for selected locations. Traffic volumes were compared for each plan on three screen lines and travel times were compared for through movements at four major signalized intersections as shown in Figure 3. Section A-A is located immediately north of Cornell Street, section B-B is located north of Columbia Street, and section C-C is parallel to the longitudinal direction of the study area and is located just east of California Street. The intersections used for travel time comparison are located along Page Mill Road at Peter Coutts, Hanover, and El Camino Real, and along El Camino Real at California.

A number of predicted volumes on the streets crossing each section and the percentage differences (compared with plan 0) are shown in Table 2. A summary of predicted travel times for the various intersectional movements and percentage differences (compared with plan 0) are shown in Table 3.

Now attention is directed toward the impacts of the six control plans on the total system. Results for the residential, arterial, and total area portions are presented in Figure 4. Three curves are drawn on each of the nine diagrams. The six plans that were evaluated are denoted on the horizontal scale. The various measures of effectiveness are indicated on the vertical scale. The thrusthold value for fuel rate was <5 miles/gal and for speed was <10 mph.

Assessment of Control Plans

The individual control plans will now be evaluated, considering the results of the previous subsection (see Tables 2 and 3 and Figure 4). Again, let it be stressed that only one point in time (January 1979) and only the effect on highway users were considered.

Plan 1 consisted of installing 10 barriers around the residential area and no modifications on the surrounding arterials. This plan had little effect either in flow levels or travel times on the surrounding arterials. While the flow level on interior streets was slightly reduced at a few locations, most locations show an increase, particularly on College Avenue. Areawide results indicated that total link flows, vehicle miles of travel, total fuel consumption, and total vehicle hours of travel increased; fuel economy rates decreased; and average speeds were unchanged. These adverse effects occurred on the residential streets as well as for the total study area. Based on these results, plan 1 was not an improvement over plan 0.

Plan 2 consisted of building an interchange at El Camino Real and Page Mill Road, with no additional actions within the study area. Flows on the arterials slightly increased, but arterial travel times were essentially unchanged except for the significant reduction at Page Mill Road-El Camino Real crossing. Flows on the collector and residential streets were slightly less. While total link flows and total vehicle miles remained unchanged, a greater proportion of travel was handled by the arterial portion of the network. Fuel consumption was reduced and fuel economy rates increased. Total travel time was reduced and average speeds increased. Based on these results, plan 2 was an improvement over plan 0 in almost every respect. However, the cost of this improvement would be significant.

Plan 3 consisted of adding a lane in each direction along Page Mill Road, with no additional actions within the study area. Flows on the arterial increased, while the travel times on Page Mill Road decreased. Flows within the residential areas were about the same except the flow at California (section A-A) decreased, while the flow at Hanover (section C-C) increased. While total link flows and total vehicle miles remained unchanged, a greater proportion was handled by the arterial portion of the network. There was little change in total fuel

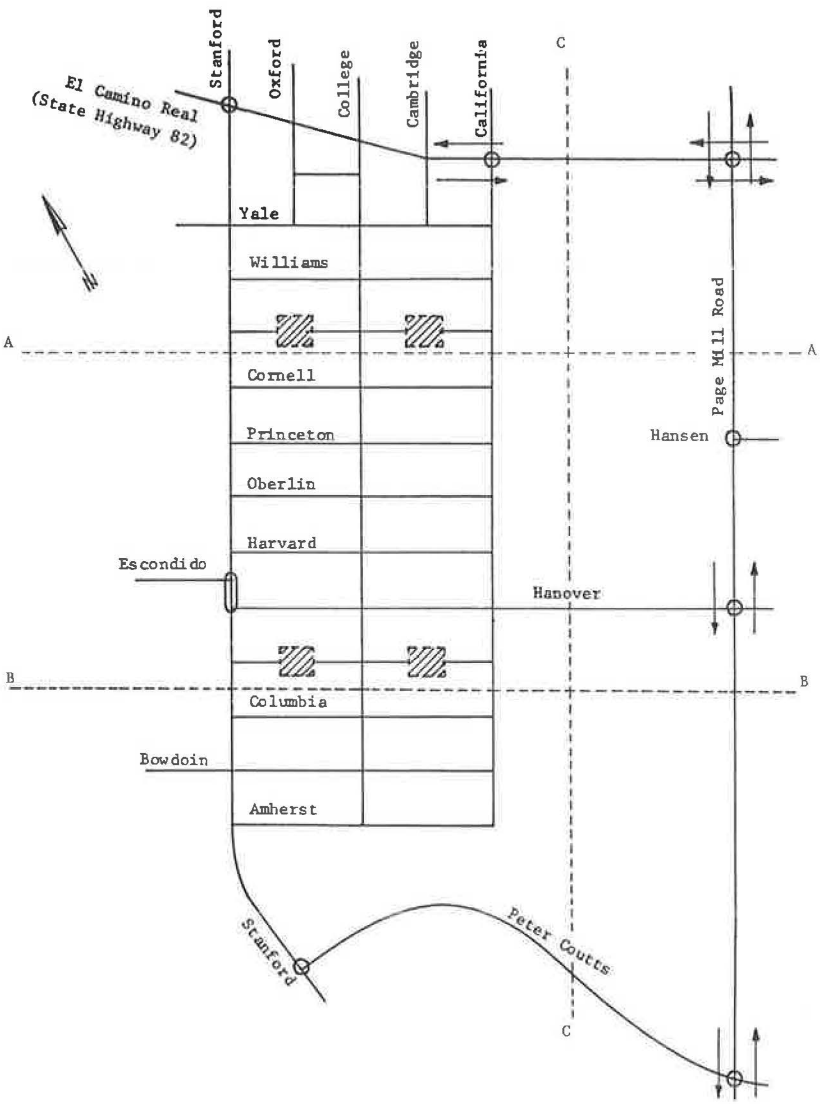


Figure 3. Selected cross sections for volume and travel time comparisons.

Table 2. Comparison of traffic volumes.

		Stanford		College		California		Page Mill	
Section	Plan	Volume	Change (%)	Volume	Change (%)	Volume	Change (%)	Volume	Change (%)
A-A	0	2160	0	208	0	1847	0	7795	0
	1	2025	-6	356	+71	1751	-5	7877	+1
	2	2146	-1	206	-1	1728	-6	7929	+2
	3	2123	-2	209	0	1637	-11	8040	+3
	4	2146	-1	206	-1	1726	-6	7930	+2
	5	2087	-3	200	-4	1461	-21	8586	+10
B-B	0	1987	0	47	0	496	0	6697	0
	1	2264	+14	584	+1150	633	+21	6578	+1
	2	1978	0	44	-1	502	+1	6548	0
	3	1960	-1	47	0	521	+5	6544	0
	4	1978	0	44	-1	502	+1	6548	0
	5	2287	+15	272	+485	685	+38	7251	+11
		El Camino		Hanover		Peter Coutts			
C-C	0	8735	0	1945	0	612	0		
	1	8755	0	1832	-6	646	+6		
	2	9127	+3	1819	-7	606	-1		
	3	8923	+2	1698	-13	610	0		
	4	9126	+3	1817	-7	606	-1		
	5	9986	+10	0	0	1751	+185		

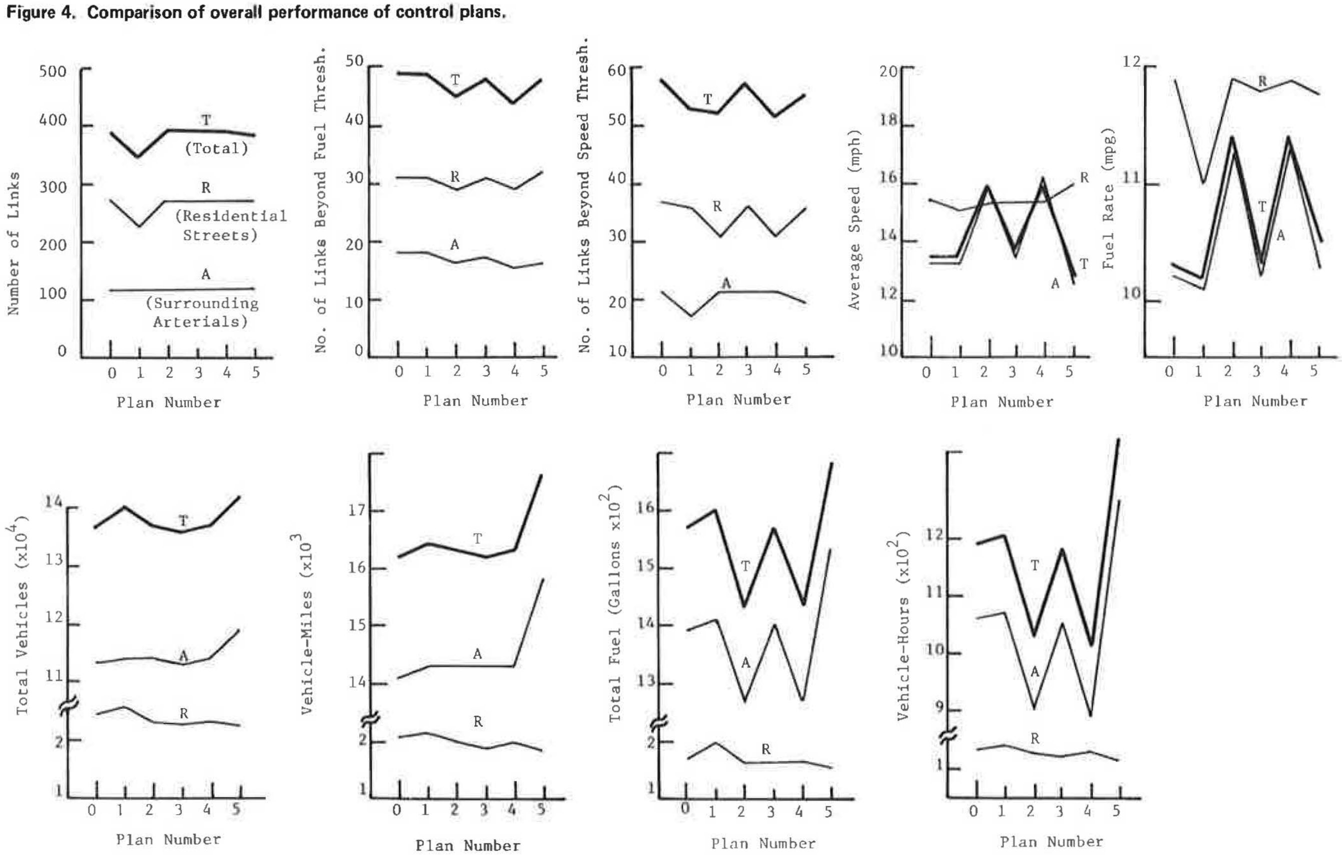
Table 3. Comparison of travel times at selected intersections.

	El Camino-California				Page Mill-California								Page Mill-Hanover				Page Mill-Peter Coutts			
	Westbound		Eastbound		Westbound		Eastbound		Northbound		Southbound		Northbound		Southbound		Northbound		Southbound	
Plan	TT	(%)[a]	TT	(%)	TT	(%)	TT	(%)	TT	(%)	TT	(%)	TT	(%)	TT	(%)	TT	(%)	TT	(%)
0	41	0	41	0	59	0	60	0	55	0	58	0	69	0	69	0	63	0	66	0
1	41	0	41	+2	59	0	60	0	55	0	58	0	69	0	69	0	63	0	66	0
2	41	0	42	+2	17	-71	18	-70	26	-53	25	-57	69	0	70	+1	63	0	66	0
3	41	0	42	+2	59	0	60	0	53	-4	56	-3	66	-4	67	-3	60	-5	63	-5
4	41	0	42	+2	17	-71	18	-70	24	-56	23	-60	66	-4	67	-3	60	-5	63	-5
5	42	+2	42	+2	59	0	60	0	55	0	48	0	68	-1	70	+1	62	-2	66	0

Note: TT = travel time.

[a]Percent change with respect to plan 0.

Figure 4. Comparison of overall performance of control plans.

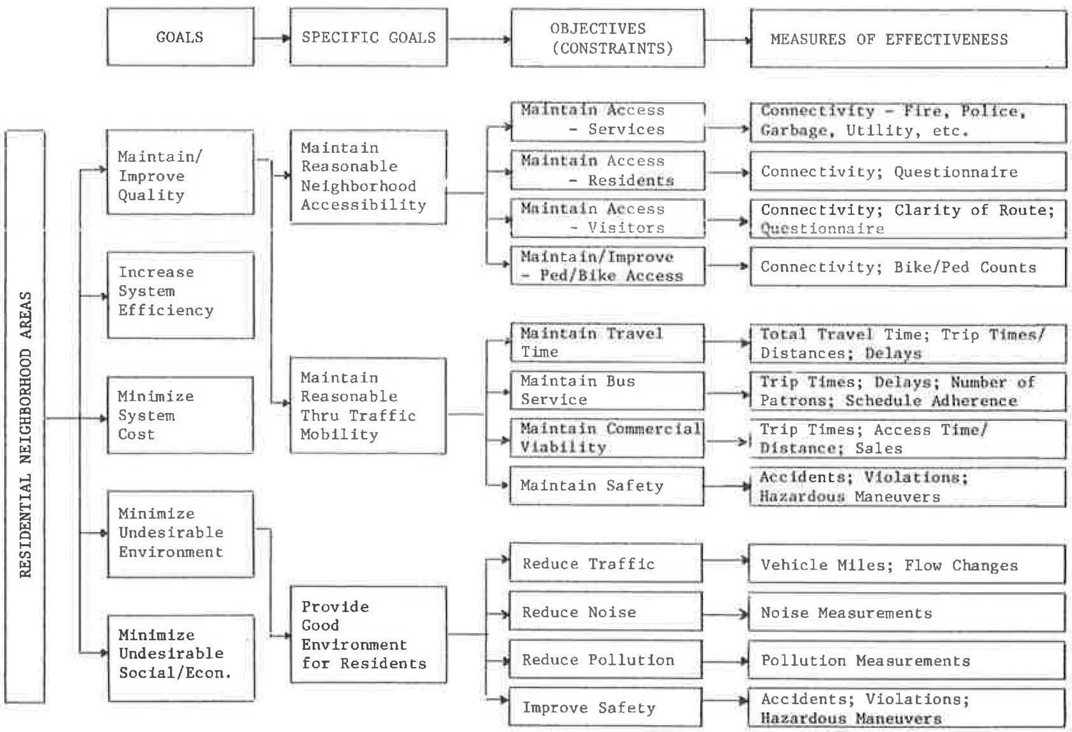


consumed and fuel economy rate. Total vehicle hours were slightly reduced and average speed slightly increased. Based on these results, plan 3 was an improvement over plan 0 and almost as good as plan 2.

Plan 4 consisted of adding a lane in each direction along Page Mill Road and building an interchange at El Camino Real and Page Mill Road crossing. No other actions were taken within the study area. Flows on the arterials slightly increased, while arterial travel times on Page Mill Road, including the crossing at El Camino Real were reduced. Flows on the collector and residential streets were slightly less. While total link flows and total vehicle miles remain unchanged, a greater proportion of travel was handled by the arterial portion of the network. Fuel consumption was reduced and fuel economy rates increased. Total travel time was reduced and average speeds increased. Based on these results, plan 4 was an improvement over plan 0 in almost every respect. Plan 4 results were very similar to plan 2 results. However, the cost of this improvement would be the highest of all plans.

Plan 5 consisted of a single barrier placed at a strategic location on Hanover just east of California. No other actions were taken within the study area. Flows on the arterials increased, while travel time on arterials only slightly increased. Flows on the collector and residential streets were reduced in the northern portion of the neighborhood and increased in the southern portion. The overall measurements for the residential portion of the study area showed significant improvements (i.e., lower vehicle miles of travel, lower vehicle hours of travel, less fuel consumption, etc.), while the overall measurements for the arterial portion of the study area showed significant disbenefits (i.e., higher vehicle miles of travel, higher vehicle hours of travel, more fuel consumed, etc.). Plan 5, when compared with plan 0, gave contradictory results.

Figure 5. Elements of traffic management in residential areas.



The neighborhood situation was improved at the expense of travel on the arterials.

Many additional control plans could have been developed and evaluated. Additional measures of effectiveness (MOEs) could have been investigated. However, the paper has presented an analytical framework and demonstrated its application, and further investigations and extensions are left to future research.

SOME INITIAL GUIDELINES

As mentioned earlier, one of the purposes of applying the MICRO-ASSIGNMENT model to the College Terrace neighborhood was to provide some insight into the development of preliminary guidelines for traffic management in residential areas. In an attempt to provide more comprehensive guidelines, traffic management studies in other residential areas were carefully reviewed. Based on this review, and with the information gained from the application to the College Terrace neighborhood, a list of goals, objectives, and MOEs was prepared and is shown in Figure 5.

In Figure 5, the specific goals for traffic management in residential areas that have often been considered are shown. These specific goals are subsets of the more general goals of improving quality of operations and minimizing adverse impacts on the operating environment. Little attention, however, has been given to other general goals such as minimizing system cost, increasing system efficiency, and so on. For the three specific goals, 12 objectives are shown along with their associated MOEs. The list shown in Figure 5 should be useful in providing the traffic analyst with the various objectives and MOEs that have been used for traffic management in residential areas.

ACKNOWLEDGMENT

We express deep appreciation for assistance given by the many persons involved with this project during the past two years and to Caltrans for its sponsorship and support in so many ways. Alan Willis of the Institute of Transportation Studies (ITS) receives our sincere thanks for his active involvement during the first year of the project. His assistance was indeed valuable and very much appreciated. Special thanks are due to D.C. Chenu (Department of Transportation Planning, Caltrans, Sacramento) for the thoughtful criticisms and comments offered as the work progressed; and to Frank C. Tedesca (Department of Transportation Planning, Caltrans, District 4) and members of his staff for their valuable assistance. We would also like to thank Dennis Robertson and his colleagues at the Transport and Road Research Laboratory for providing a copy of the CONTRAM program. Robertson's visit to ITS and his thoughtful critiques significantly contributed to the evaluation of models. Particular note is made of the contributions to the data-collection efforts and model calibration by Kent Dewell (Public Works-Transportation, city of San Jose, California) and members of his staff. Their willingness to review the calibration results several times significantly improved the application to the central business district of San Jose. Special thanks are also extended to Ted Noguchi (Transportation Division, city of Palo Alto) and members of his staff for their contributions to the data-collection efforts and for reviewing the calibration results. Undoubtedly, their continued input during the course of this project is reflected in the application work to the College Terrace neighborhood. Finally, Phyllis De Fabio deserves special thanks for the excellent typing service.

REFERENCES

1. S.M. Easa, T.L. Yeh, and A.D. May. Traffic Management of Dense Networks, Final Report: Volume 1, Analysis of Traffic Operations in Residential and Downtown Areas. Institute of

Transportation Studies, Univ. of California, Berkeley, UCB-ITS-RR-80-5, June 1980.
2. S.M. Easa, T.L. Yeh, and A.D. May. Traffic Management of Dense Networks, Final Report: Volume 2, User's Guide of the Refined Micro-Assignment Model. Institute of Transportation Studies, Univ. of California, Berkeley, UCB-ITS-RR-80-6, June 1980.
3. S.M. Easa, A.E. Willis, and A.D. May. Traffic Management of Dense Networks: Existing Experience and Analytical Techniques. Institute of Transportation Studies, Univ. of California, Berkeley, UCB-ITS-WP-78-11, Dec. 1978.
4. A.E. Willis, S.M. Easa, and A.D. May. Traffic Management of Dense Networks: Model Evaluation and Site Selection. Institute of Transportation Studies, Univ. of California, Berkeley, UCB-ITS-WP-79-5, July 1979.
5. T.E. Mulder. A Temporal Micro-Assignment Model. Chicago Area Transportation Study Report, 1973.
6. D.R. Leonard, J.B. Tough, and P.C. Baguley. CONTRAM: A Traffic Assignment Model for Predicting Flows and Queues during Peak Periods. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, TRRL Laboratory Rept. 841, 1978.
7. D.R. Leonard and J.B. Tough. Validation Work on Contram: A Model for Use in the Design of Traffic Management Schemes. Traffic Engineering Department, Transport and Road Reseach Laboratory, Crowthorne, Berkshire, England, 1979 (to be published).
8. Developing a Procedure for Comparing Alternate Urban Highway Network Improvement. Wilbur Smith and Assoc., San Francisco, 1969.
9. Creighton-Hamburg, Inc. Micro-Assignment, Final Report: Volume 1, Procedure and Theoretical Background, and Volume 2, Program Documentation. Bureau of Roads, Federal Highway Administration, U.S. Department of Transportation, Oct. 1969.
10. G.H. Brown and R.S. Scott. Micro-Assignment: A New Tool for Small Area Planning. HRB, Highway Research Record 322, 1970, pp. 149-161.
11, John Hamburg and Assoc., Inc. MICRO/UROAD User's Guide. U.S. Department of Transportation, Aug. 1978.
12. UROAD: Highway Traffic Assignment Program. Urban Mass Transportation Administration, U.S. Department of Transportation, 1979 (unpublished notes).
13. J.A. Charlesworth. Mutually Consistent Traffic Assignment and Signal Timings for a Signal-Controlled Road Network. Transport Operation Research Group, Division of Transport Engineering, Department of Civil Engineering, Univ. of Newcastle-upon-Tyne, England, Research Rept. 24, 1977.
14. S.M. Easa, A.E. Willis, and A.D. May. Traffic Management of Dense Networks: Application and Evaluation of Two Network Traffic Models. Institute of Transportation Studies, Univ. of California, Berkeley. UCB-ITS-WP-79-14, Oct. 1979.
15. D.C. Chenu. San Jose Central Business District Project: Validation of Micro-Assignment and Evaluation of Two Loading Procedures. Department of Transportation Planning, California Department of Transportation, June 1977.

Publication of this paper sponsored by Committee on Social, Economic, and Environmental Factors of Transportation.

Resource Implications of Electronic Message Transfer in Letter-Post Industry

ALFRED M. LEE AND ARNIM H. MEYBURG

As Western societies move more and more rapidly to information economies, the need for face-to-face human interactions and for the exchange of physical goods is being replaced by the need to exchange information. New technologies have been and are being developed that facilitate this flow. The impacts of this change in orientation are many. Substitution of personal travel and hard-copy communications transport by electronic means is a significant social development with implications for energy consumption, vehicle fleet, paper, and labor requirements, among others. This paper attempts to illustrate some of the impacts of substituting communication for transportation. The use of electronic message transfer technology by the U.S. Postal Service is examined in the context of current first-class mail shipment patterns. Limited energy, vehicle, and paper resource conservation possibilities could be enhanced by implementing policies to stimulate the development and use of electronic message transfer technologies.

Western societies are moving at a rapid pace toward information societies. The information flow required per person in personal life-styles, in research, in administration, in all service industries, etc., is increasing dramatically. All aspects of daily life and of society in general are affected by this acceleration in the exchange of information. Few households are without telephones or televisions. Banks and travel agencies without computers are rare. Government recordkeeping would be virtually impossible at the present scale without the extensive use of electronic devices.

Transportation and communications are closely related infrastructural elements of society (1). These modes are used to enhance and facilitate exchange in the national and international economy and to increase the level of human interaction. As society moves toward an information economy, the need for exchange of goods, defined in a very broad sense, is being replaced by the need to exchange information. This evolution is changing the nature of demand for these services.

In some instances communications may substitute for particular transportation needs. In other cases, they may be complementary. Patterns of telephone use serve as an example of the substitution potential of communications for transportation. Telephone communications have reduced the need to transport various kinds of messages and also