

they both contain zonal data used for analyses such as trip generation.

The downloading should result in as few diskettes as possible. Careful review should be made of specific uses anticipated and only those data expected to be used should be downloaded.

ACKNOWLEDGMENT

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Computer Graphics Techniques for Use with the Urban Transportation Planning Package

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ABSTRACT

The Urban Transportation Planning Package (UTPP) is a special tabulation of 1980 census questionnaires that provides detailed information on commuter flows and related data within the urbanized portion of Standard Metropolitan Statistical Areas (SMSAs). Four computer graphics techniques are described that assist transportation planners in analyzing and utilizing the UTPP data: automated choroplethic mapping; FLOWMAP, a geographic flow-mapping system; FLOGRAF, a program to display network traffic flows; and TRANES, a data retrieval and display system for transit route planning. A description of each technique is provided along with suggested applications using UTPP data. Sample graphics displays from the techniques are included.

The data-intensive nature of urban transportation planning places special demands on local planning agencies for data gathering and upkeep. To assist in this process the Bureau of the Census provides a special tabulation of 1980 census data called the Urban Transportation Planning Package (UTPP). Derived from questionnaires from the 1980 census, this package contains detailed information on commuter flows and related data within the urbanized portion of Standard Metropolitan Statistical Areas (SMSAs). The package can be used to study and evaluate current travel conditions and to apply and calibrate planning models used to simulate current and future conditions.

Like any large data set, the UTPP is too voluminous to be easily analyzed in its raw tubular form, even with the aid of electronic computers. Summary statistics and graphical techniques are among the

methods used to render the data more readily comprehensible. Computer-assisted graphics techniques, in particular, are useful to facilitate quick yet detailed analyses of the UTPP data.

Four computer graphics techniques are described that assist transportation planners in analyzing and utilizing the UTPP data. These techniques can be used to manipulate and display the raw data or they can be used in conjunction with transportation models that accept the UTPP data as input. The first technique, automated choroplethic mapping, is a method to produce shaded-area maps that display socioeconomic and travel-related characteristics by census tract or traffic zone. The second, FLOWMAP, is a data display program that plots urban commuter flow patterns on a computer graphics plotter or graphics terminal. The third, FLOWGRAF, is an interactive graphics package that is designed to aid the analysis of urban travel on congested highway networks. The fourth, TRANES, is a data retrieval and display system for transit route planning and evaluation.

Although not designed specifically for the UTPP, these four techniques are well suited to the task of UTPP analysis. Choroplethic mapping provides an effective method for browsing and comparing the socioeconomic information contained in Parts I, II, and III of the package (see Table 1). Part IV of the UTPP, trip tables from the place of residence to the place of work, can be used as input to FLOWMAP to display the census journey-to-work data in graphic form. When these journey-to-work trips are assigned algorithmically to a computerized version of the street network, the resultant traffic patterns can be displayed using FLOWGRAF. The same data can be used with TRANES to evaluate how well alternative transit routes serve the journey-to-work travel demand to one or more employment centers.

AUTOMATED CHOROPLETHIC MAPPING

Choroplethic mapping is a process in which quantita-

TABLE 1 Component Parts of the 1980 UTPP (1)

Part	Description	No. of Tabulations	No. of Data Items
I	Tabulations by census tract or block group (or zone-special order) of residence	29	773
II	Tabulations by large geographic areas of residence	19	11,642
III	Tabulations by census tract (or zone-special order) of work	14	517
IV	Tabulations by census tract of residence to census tract of work (or zone of residence to zone of work-special order)	3	30
V	Tabulations by block group of work (subtotals to census tract of work)	7	107
VI	Tabulations by county of residence to county of work (includes up to 20 external counties or New England towns with a large number of journey-to-work trips)	10	322
Total		82	13,391

tive information is displayed in a geographical context using polygonal geographic boundaries and a range-graded symbolization scheme. Typically, areal data collection units such as census tracts, counties, or states are shaded on the map according to their respective quantitative magnitudes. Choroplethic maps serve to augment tabular statistics in order to more aptly display the spatial patterning of the information.

In recent years a number of computer programs have become available that allow a user to quickly and easily generate high-quality choroplethic maps on computer output devices. (Figures 1 and 2 are examples of computer-generated choroplethic maps.) These programs accept as input statistical data,

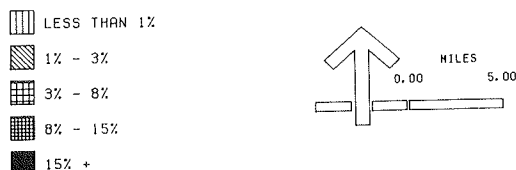
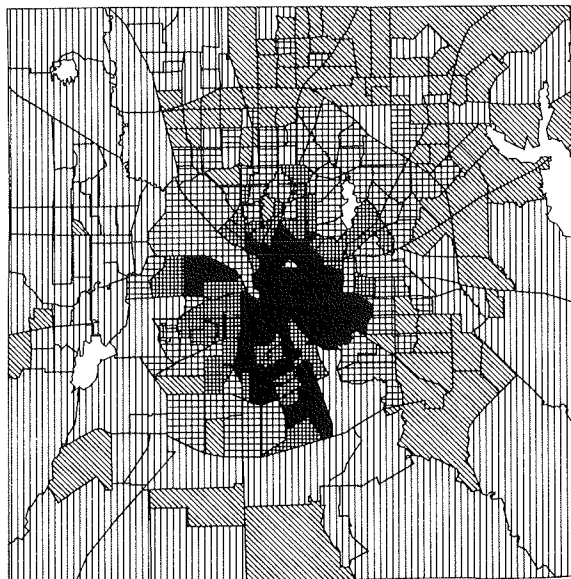


FIGURE 1 Percentage of workers riding public transit to work.

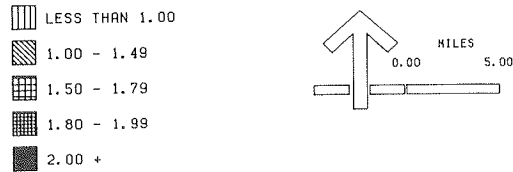
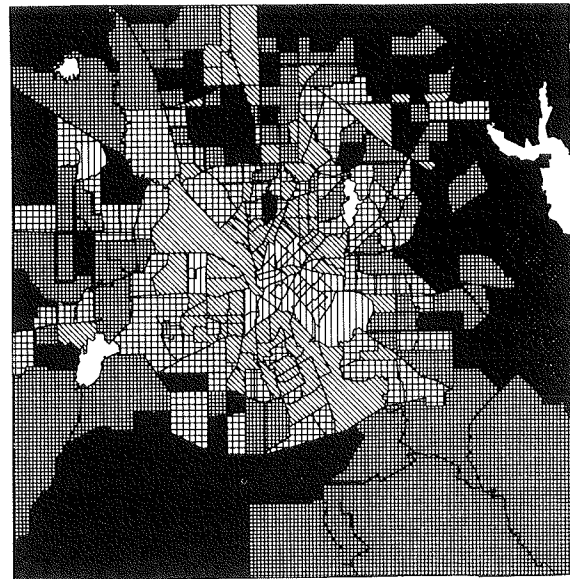


FIGURE 2 Average number of vehicles available per household.

such as census data, and geographical data describing the boundaries of the areas to be mapped. With a variety of program commands or parameters, the user controls various aspects of map design and symbolism, such as shading categorization and title placement.

For transportation planners using UTPP data, automated choroplethic mapping can provide an excellent tool for summarizing and reporting data. Applications of this type include the following (2):

- Evaluation of characteristics at the residence end and work end for population, housing, and employment;
- Summarizing, reporting, and analyzing 1980 conditions for journey-to-work trip lengths, mode use, carpooling, and travel times;
- Evaluation of changes in journey-to-work travel such as changes in mode of travel, vehicle use, and so on, by comparing 1970 and 1980 census data.

In addition to summarizing and reporting, the choroplethic mapping technique is useful in a variety of other analytic applications. For example, shaded-area maps of census data have been used for transit planning in a technique known as successive overlays (3). In this process, selected transit-related variables such as car ownership, income, and percentages of elderly and young populations are plotted on individual transparent map sheets that can be used as successive overlays with the street network as a base. In this way, potential areas of high transit patronage can be identified for use in evaluating alternative transit routing strategies.

In general, automated choroplethic mapping is useful in displaying the geographic distribution of static phenomena in an urban area. To represent movement across space such as traffic flow, other graphics techniques are more appropriate.

FLOWMAP

Origin and destination (OD) studies are conducted regularly by transportation planners for a number of purposes. The OD trip tables produced in these studies provide insight into the geographic travel patterns of urban commuters for purposes of transportation facilities planning and investment. They are also used to calibrate trip distribution functions that model zone-to-zone travel patterns in an urban area. As important components of regional transportation planning efforts, OD studies typically consume a large portion of an agency's data-gathering resources. This cost can be at least partially offset by using the OD trip tables in Part 4 of the UTPP.

Unfortunately, the information in OD tables is not easily summarized in graphic form, which limits the planner's ability both to comprehend and to communicate the data. This is due to the difficulty of representing complex travel patterns using conventional graphics techniques. Flow maps can be used effectively for this purpose, but they are difficult and time-consuming to prepare. In these maps, commuter flows are displayed as variable-width arrows or bands, where the width of each arrow is proportional to the magnitude of the flow it represents. In order to produce a coherent display of this type, a considerable amount of data reduction and map manipulation is required.

FLOWMAP (4) is an interactive graphics program designed to overcome the inherent problems of flow-map production. It provides a variety of automated map design options so that maps can be generated on a trial-and-error basis and modified until the desired result, a comprehensible map, is obtained. FLOWMAP provides the user with the ability to examine OD data much more comprehensively than has been possible in the past, with ease and minimal cost. It also enables the production of report-quality maps or large wall-size displays for communicating results to others.

FLOWMAP displays flow primarily as arrows, but

proportional circle and pie-graph maps can be drawn to illustrate internal flows (trips that originate and terminate in the same zone). Five generic types of flow maps are possible:

1. Interzone flows are displayed as variable-width arrows with the width of the arrow proportional to the volume of flow (see Figure 3),
2. Net flows show the difference between the incoming and outgoing flows for each of several pairs of zones and are represented as variable-width arrows that point in the direction of the larger flow,
3. Internal flows are displayed as graduated circles with the area of the circle proportional to the flow volume,
4. Origin pie graphs show a circle that has an area proportional to the total flow that originates in the zone and a shaded sector proportional to the internal flow (see Figure 4), and
5. Destination pie graphs are similar to origin pie graphs but show the total flow that terminates in the zone.

FLOWMAP may be run in interactive mode or in plotter mode. Interactive use requires a Tektronix 4010-compatible interactive graphics terminal. Hard-copy units are available for these devices, which inexpensively reproduce what appears on the screen. Higher-quality paper copies can be drawn from plotter mode by using a pen or electrostatic plotter. A typical use of the program would proceed as follows: (a) design the map interactively at a graphics terminal, (b) save the set of instructions to produce that particular map, and (c) execute these instructions in plotter mode to draw the final map on paper at the desired size.

FLOWMAP requires input data from two files: a flow-data file and a geographic feature file. The flow-data file is divided into three sections: a map instruction section, an OD table, and a point location section.

The map instruction section contains the number of interacting geographical areas (usually traffic

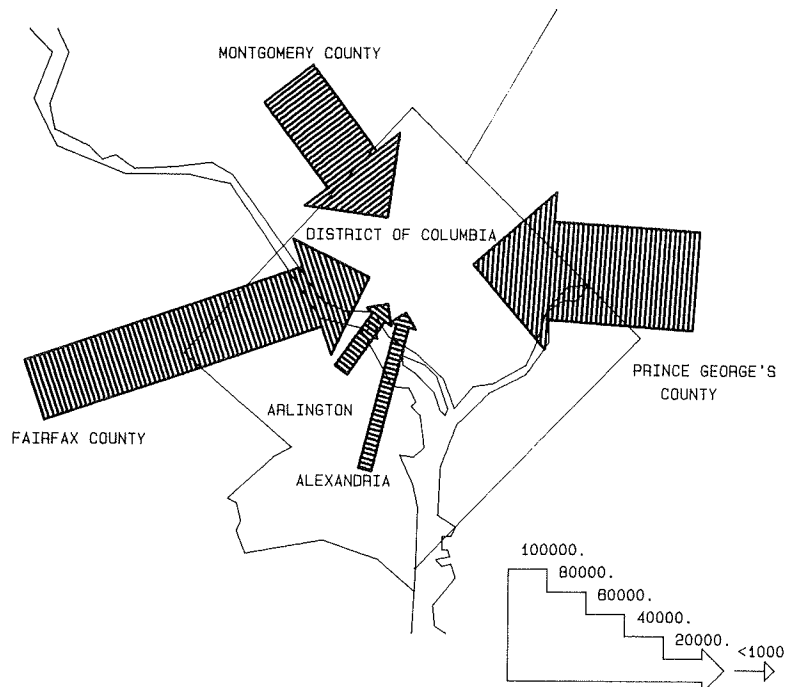


FIGURE 3 Home-to-work automobile driver trips: 1980.

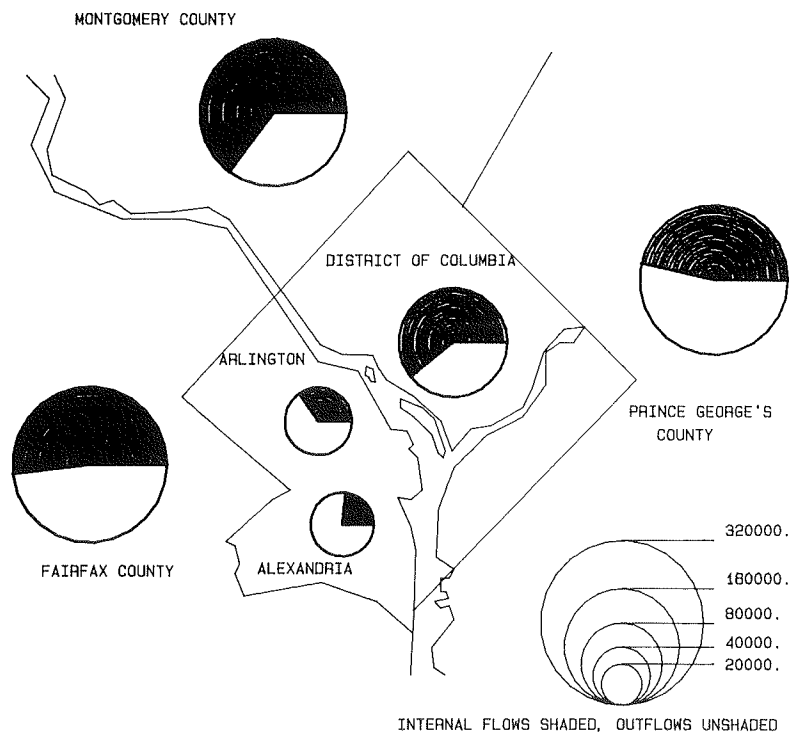


FIGURE 4 Home-to-work origin pie graphs: 1980.

zones) that are included in the OD table. The remainder of the instruction set includes a map title and optional parameters that allow the user to control various aspects of map design. With these parameters the user can designate the type of flows to be shown and choose among several map display options.

The OD table is a matrix in which the left tab represents the "from" zones and the top tab represents the "to" zones. Thus, the data value located in row 2 and column 3 is the volume of flow from zone 2 to zone 3. This matrix can be derived from Part IV of the UTPP.

The point location section consists of a set of X- and Y-coordinates that identify a reference point for each traffic zone. These locations are used to define the starting and ending points for the flow arrows. They can be located anywhere inside a zone, such as the geographic center of the zone. Also included in this section are the names or numbers of each zone and the X- and Y-coordinates for the map location of each name.

Once the input data have been prepared, the user may elect to display interzone flows, net flows, internal flows, or pie graphs. Many-to-many, many-to-one, or one-to-many flow maps may be drawn.

Many-to-many maps are the default type. All non-zero flows in the OD matrix are displayed, although small flows can be eliminated. The user may select long arrows that extend from the origin to the destination or short arrows with annotated destinations. In some cases, the short-arrow option will improve map clarity. The user can also select curved arrows, so that inbound and outbound flows are not superimposed.

Many-to-one maps display all incoming flows to one destination and one-to-many maps display all outgoing flows from a single origin. The operator decides whether a zone is active as an origin or destination for each map drawn. For example, if all zones are active origins and only one area is an active destination, a many-to-one map will be pro-

duced. It is possible to show several many-to-one or one-to-many displays on the same map.

Net flow maps display arrows that show the difference in flows between each pair of points. Internal flow maps produce no arrows but draw a circle with area proportional to the internal flow for each zone. Pie-graph maps show circles proportional to total flows beginning or ending in each zone; internal flows are represented as a shaded slice of each circle.

FLOWMAP has been found to be a useful tool for displaying flow data for two main reasons. First, it decreases total map production time through the use of interactive design. The user's time and design abilities are used more productively in the designing process. Minor problems such as overlapping text becomes trivial to correct using interactive procedures. This allows additional time to be spent on more substantive map design problems.

A more important advantage of FLOWMAP is that it allows the user to explore a data set thoroughly before creating final maps tailored to particular concerns. By alternately requesting many-to-one, one-to-many, and many-to-many maps, the user can quickly determine the best way to show the significant portions of the flow matrix. This type of flexibility is not available by using traditional cartographic techniques. It should facilitate the discovery of potentially important relationships in the data that might otherwise go unnoticed.

FLOWGRAF

FLOWGRAF is an interactive color graphics program designed for displaying data that relate to the level of traffic congestion at various times of day. This is accomplished by plotting a map of the highway network on a color graphics terminal and color coding each highway link based on the amount of congestion on that link. A key is drawn along side the map indicating the level of congestion denoted by each

color. Although the map color selection is user specified, generally a hot color such as red is used to shade highly congested links, and a cool color such as blue is used to shade relatively congestion-free links. Congestion can be measured alternatively by the number of vehicles per lane kilometer, the number of vehicles per lane, the number of vehicles per kilometer, or the number of vehicles.

Schneider (5) has identified several ways in which these types of displays can be used to support the transportation planning process. First, they could be helpful in identifying and summarizing highway congestion problems by allowing the easy mapping of various indices of congestion. Second, they could help the transportation planner interpret the results of simulation models that are designed to predict the impact of various transportation policy decisions. Third, they could assist the interpretation of field data gathered in before-and-after studies associated with small-scale short-term experiments designed to test various congestion-reduction techniques in various settings. Finally, they could be similarly helpful in evaluating the impacts of congestion reduction techniques that were implemented by simulation.

An important feature of FLOWGRAF is that it allows the user to visualize traffic congestion over time, providing a temporal as well as a spatial perspective. This is significant in that it enables the user to more easily think about the complex urban traffic interactions on a holistic basis (6). For transportation modeling efforts that attempt to gauge the impact of planned congestion reduction policies, this is a valuable capability. For example, a technique that relieves congestion in one part of the network might only serve to increase congestion in another part of the network in the same or a different time frame. These relationships become more apparent when viewed in a time series of graphical displays.

The required data for FLOGRAF displays can be derived from Part IV of the UTPP, using simulation models designed to replicate or forecast the flow of vehicles on a street or urban freeway network. These models are well suited to the task of projecting the probable impacts of alternative congestion reduction strategies. Examples of these types of models are found in the Urban Transportation Planning System (UTPS) family of programs.

FLOSIM is a simple but useful simulation program that serves as a companion program to FLOGRAF. It is essentially a network assignment model that takes OD trip tables and loads them onto a computerized representation of the urban transportation network. Various indices of traffic congestion, such as volume-to-capacity ratio, can then be displayed at a color graphics terminal using FLOGRAF.

FLOSIM performs the operations necessary to simulate the flow of traffic in an urban network in three steps (6). The first program of the series, MINTREE, builds a file containing the shortest path in travel time between all pairs of nodes in the network. The second program, TRAFSIM, reads origin, destination, volume of traffic, and starting times from a data file. It accesses the appropriate minimum-path tree and simulates the flow of traffic between each OD pair. Because the clock time at each node along the minimum paths is known, the program can determine which link contains each group of trips at any particular observation time. The flows are sorted and aggregated by link in the third step of the process. This output forms the link congestion information that is displayed by FLOGRAF on the color graphics terminal.

To use FLOGRAF with simulation data, three steps must be completed:

1. The street network must be coded as a series of links and nodes so that it can be input to the computer. The X- and Y-coordinates of each node and the number of lanes and speed of each link must be recorded.

2. OD flows must be assigned to the network using FLOSIM (or a more sophisticated simulation model). This distributes the flow of traffic over the street network and calculates traffic volumes on each link in the network at prescribed observation times.

3. The FLOGRAF program is then used to produce color maps of the link traffic volumes on a color computer graphics terminal. Currently a Tektronix 4027-compatible terminal is required, although it is conceivable that a microcomputer could be used, given the appropriate communication and emulation hardware and software add-ons.

TRANSIT NETWORK EVALUATION SYSTEM: TRANES

TRANES is an interactive computer graphics program designed for transit system route planning and analysis. It uses computerized street network files and data from the 1980 census to retrieve information on the number and type of potential transit users within a specified distance of transit facilities. TRANES was originally developed for large computer systems by Johnston and others (7) and has recently been converted to the IBM personal computer by Schlesenger (8). The program has been applied to a variety of transportation and other network problems, including alternative bus and light rail route evaluation; determination of optimal location of bus, rail, and other transit stops; and medical emergency station location analysis.

TRANES has two primary applications that are of major concern to the transportation planner. First, it can be used to evaluate the accessibility of various subgroups of the population to transit facilities. Second, it can be used to measure the propensity for transit use of alternative route configurations based on the number and type of potential transit riders with access to each route.

The first application, accessibility analysis, is used to measure the effectiveness of transit in providing transportation to low-income and minority groups, who often cannot afford to own and operate automobiles. One of the main goals of public transit is to help provide access for these groups to employment, educational, shopping, recreational, and social opportunities. TRANES provides an efficient vehicle to measure transit accessibility by combining population stratifications from census data with local transit route descriptions.

The second major application provides planners with a quick and easy method to assess the potential success of alternative transit routes. By accessing appropriate census variables through the TRANES reporting capabilities, an overall index of propensity for transit use can be constructed for each route. The objective is to identify transit routes along the road network that serve areas in which the population exhibits socioeconomic and demographic characteristics similar to those of typical transit riders. In one study (3) the following variables have been found to be important in predicting transit use: the number of passenger cars per dwelling unit, average household income, the number of females aged 16 to 24, the number of persons aged 62 or over, and the number of dwelling units per acre. Other variables are available from the 1980 census that could provide additional information.

To run TRANES, a user first selects the area of the urban street network containing the transit

route or route segments to be analyzed. Two pre-processor programs are then run to produce the input files needed for TRANES. The user identifies transit stops and routes to be studied and specifies a maximum walking distance from each stop. The TRANES program can then be activated to delineate all possible paths from each stop that terminate within the specified distance. The census information related to the street links along those paths is then allocated to the appropriate transit stops. Socioeconomic profile reports can be produced either for individual stops or for entire routes. The process can be continued iteratively to evaluate alternative route designs.

A major advantage of TRANES is that it uses readily available high-quality geographic and socioeconomic data provided by the Bureau of the Census. The data are available at low cost and they are already in machine-readable form. Because of this, no extensive data collection or data entry effort is required and start-up times for TRANES projects can be kept to a minimum.

TRANES requires two types of data files as input: a street network file and a census data file. The street network file is derived from the Census Bureau's Geographic Base File and Dual Independent Map Encoding (GBF/DIME) file, commonly called the DIME file. The DIME file is a computer-readable description of all street segments in a metropolitan area with segments typically defined as street links bounded by street intersections. Other segments may be defined by nonstreet features such as lake shores or railroad tracks. Each segment is represented by a record in the file consisting of (a) the two digitized nodes that define the segment end points, (b) the name of the street or geographic feature, (c) the address ranges between nodes for both sides of the street, and (d) the left and right census geography for the segment (tract number, block number, etc.).

This information constitutes the basic link and node data that are needed for computer-assisted transportation network analysis. Each node is uniquely numbered and contains coordinate values that enable plotting the network on a plotter or computer graphics terminal. The walking distance along each link can be computed by using the straight-line distance between the two nodes.

The DIME file defines the relationship by which census socioeconomic and travel demand data can be disaggregated from polygons to street links for use by TRANES. The UTPP census data file can be accessed to assign a demographic value to every addressable street link in the DIME file. DIME records with no address range are not included because it is assumed that they represent links where there are no residences (e.g., freeway ramps). In addition to total population, other variables such as total minority population, elderly and teenage population, low-income households, and number of households with no automobiles available can be used. When TRANES is activated, it totals the values of all the street segments that lie within a given distance of user-specified transit stops. These segments are displayed graphically on the computer screen (see Figure 5) and the value totals can be printed out in report form. (In Figure 5, the lightly shaded area indicates the links that have been allocated by the path-building module.)

The user has three options regarding the disposition of the output report. The program can store the report on a diskette for later display and analysis, route the report to the printer, or display the report on the monitor. A sample report is presented in Table 2.



462 links reached
Please press <spacebar> to continue

FIGURE 5 TRANES street network display.

TABLE 2 TRANES Allocation Report

Node	Total Population by Miles		Households by Miles		Housing Units by Miles	
	0-0.1	0.1-0.25	0-0.1	0.1-0.25	0-0.1	0.1-0.25
115	99	472	37	188	38	192
126	67	565	30	262	31	272
155	18	71	10	44	10	44
180	33	475	15	240	15	252
194	22	415	11	228	11	250
Total	239	1,998	103	962	105	1,010

SUMMARY AND RECOMMENDATIONS

Computer graphics provides invaluable tools for displaying, analyzing, and communicating the information contained in the 1980 UTPP. As exemplified by the four techniques presented, computer graphics enhances, complements, and expands other analytic methods used in conjunction with these data. These techniques should be considered integral parts of the transportant planner's analytical tool kit.

To facilitate the use of these techniques with UTPP, FLOWMAP, FLOGRAF, TRANES, and a choroplethic mapping program could be distributed as part of the UTPP package along with the report-writing software already included. In addition, the programs could be made more readily compatible with the UTPP data format, so that major reformatting and preprocessing of the data would not be required for their use.

A second recommendation for improvement of FLOWMAP, FLOGRAF, and TRANES is to make them compatible with a general travel demand modeling system. The programs currently operate as data retrieval and display systems and have no modeling capabilities of their own. An obvious choice would be to make the programs compatible with the UTPS system of integrated transportation models. An alternative prospect would be to include these programs in the quick-response series of programs for short-term transportation modeling (9). For transit systems planning, a functional integration with the Transit Operations Planning (TOP) (10) package could be valuable.

In lieu of these prospects, another opportunity for enhancement is to make FLOWMAP, FLOGRAF, and TRANES internally compatible with each other, creating an integrated system of transportation planning computer graphics software. This would enable a user to begin with the UTPP zone-to-zone travel demand, analyze the flows in graphic fashion, observe

where congestion on the highway network will result from this demand, and design transit systems that could potentially serve the demand. A system of this kind would be especially useful if it operated on a microcomputer, which would make it available to a large number of potential users.

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