4. Two types of performance charts graphically summarize a great deal of information on (a) individual paths through the station and (b) the population and area per person in a particular space.

The last two types of graphics were developed by the authors from data already present in one form or another in USS reports.

Although the use of these graphics was described in the specific context of the USS computer program, their use is open to application in many other types of design problems that involve movement of people and vehicles. The use of computer graphics, and especially the development of the innovative display techniques demonstrated in this application, serve to highlight problem areas and focus attention on specific aspects of simulation modeling. Graphic tools provide a superior format for computer output that enables the designer and the analyst to interpret the simulation results more quickly and apply them to the design problem.

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Use of Interactive Computer Model STREAK for Transportation Planning

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STREAK, an interactive set of computer programs for transportation planning, is described in both nontechnical and technical terms, and some experience in its use is discussed. The program uses portable desk-top terminals and conventional telephone lines. Outputs on the portable terminal include responsive dialogue (questions and answers), tabular arrays, and data plotted by coordinates for use with overlaid maps. Capabilities of the model include multimodal network development, pathfinding in multimodal networks, travel demand estimation for all modes, travel assignment, and outputs in map coordinates or tabular form under direct user control. The primary advantage of STREAK in planning studies is its ability to evaluate and report findings on an alternative in a matter of seconds. A secondary advantage is the ease with which the model performs data corrections and network modifications directly via the terminal. The model has proved its value in several studies.

An interactive set of computer programs has been developed to assist planners with problems that require the testing of many candidate solutions. Although primarily designed for sketch-planning studies, the programs have proved to be useful for a variety of planning problems including many that involve only a few alternative solutions. The programs, called Strategic Transportation Evaluation and Analysis Kit (STREAK), are actuated by means of a portable desk-top terminal and a conventional telephone line. The purpose of this paper is to describe the role of STREAK in the planning process, provide a brief technical description of the models, and discuss experience to date with their use.

STREAK AND THE PLANNING PROCESS

STREAK is well suited for network evaluation, travel demand forecasting, locational analysis, and accessibility calculations. Though primarily intended for sketch planning, it can also be used for detailed studies of small to medium-sized areas.

The major capabilities of the model include the following:

1. Multimodal network development and modification in which links can be rapidly added, deleted, or modified (specifically or by class codes) to activate alternative systems such as highway networks, bikeways, pedestrian paths, or bus lines on highway links;
2. Non-line-specific coding scheme for simplified transit network representation, which significantly reduces the time required to evaluate alternative transit networks;
3. Pathfinding in multimodal networks, subject to a variety of user-specified constraints;
4. Travel demand estimation by use of default trip distribution and mode-split models, default models with user-selected parameters, or user-specified trip distribution and mode-split models;
5. Assignment to optimal paths via minimum time, cost, or combined impedance; and
6. Inputs and outputs displayed in map (printer plot) or tabular form under direct user control.

STREAK essentially provides the same capabilities as standard transportation planning packages: network development, updating, pathfinding, travel demand projection, trip assignment, and so on. Assuming the same network and parameters, STREAK will produce results similar to those produced by other transportation planning packages. The major advantages of STREAK over standard batch processing are

1. Near-instantaneous response to many "what if" questions that a planner should ask in designing or evaluating a transportation system,
2. Minimal processing time, and
3. Quick and easy modification of network data, which permits many alternatives to be tested rapidly.

Although STREAK could be used for much of the standard work of travel estimation, its conversational capabilities are best suited to the following areas:

1. Initial development of transportation network alternatives, especially corridor evaluation, technology assessment, or alignment studies;
2. Comparative accessibility analyses of alternative networks to measure how well each system provides service to jobs, activity centers, population concentrations, transit dependents, or other relevant groups;
3. Location studies of public facilities such as transit stations, fire stations, schools, or activity centers to provide quantitative inputs in testing of alternative locations;
4. Immediate evaluation of proposals and suggestions in meetings of the public and planning committees.

STREAK operates in an interactive mode. The fundamental assumptions that underlie interactive planning are the following:

1. Overall network system performance can be evaluated on the basis of how a limited number of major or typical destinations are served—i.e., by evaluating an alternative network based on travel between all zones and, say, only the downtown area, the airport, a major shopping center, and a typical residential zone.
2. Locations of stations (or other facilities) can, in a first-cut approach, be analyzed on the basis of accessibility to population and employment sites—i.e., without regard to travel demand.

These two assumptions differ significantly from the standard practice of processing all zone-to-zone trips.

In the two cases above, influence areas, travel-time contours, service levels, patronage estimates, capacity evaluations, and link loadings can be provided in a matter of seconds by using a time-sharing environment and a limited number of representative destinations. An analyst would then keep modifying station locations, spacings, network connections, speeds, frequencies of service, and mode-choice parameters to improve the alternative. At the same time, he or she would be doing a sensitivity analysis of the alternative. The final plan developed in this fashion should be fully evaluated in the standard manner by processing all zones. This can be more economically produced off-line, but using the results of the STREAK analyses can make the batch runs far more cost-effective.

The interactive methodology, therefore, only complements and does not replace standard batch processing. Properly used, it should greatly increase the quality and scope of the comprehensive planning process and provide a variety of useful evaluation measures. It also lends itself to immediate answers at meetings and sessions, helping to channel discussions into profitable and concrete (as opposed to speculative) directions.

The planner communicates with STREAK in a brief but powerful command vocabulary. One subset of commands modifies the network components: nodes, links, and their attributes. Another subset is used to control the operation of STREAK pathfinding and other algorithms. A third subset modifies the models by imposing constraints, redefining parameters, or providing alternate sources of input. A final subset causes data to be displayed in report and printer-plot format.

TECHNICAL DESCRIPTION OF STREAK

The STREAK interactive computer program contains several standard transportation planning functions within one logical shell. The program is amenable to sketch and detailed planning studies that involve composite-mode, abstract, or conventional transportation networks. STREAK is written in FORTRAN and is operational on the CDC NOS system.

Planning Network

The input network is composed of links and nodes. The user selects a subset of nodes to serve as zone centroids (trip-end locations) or sources (roots of minimal impedance trees). Network encoding is simplified by a novel scheme that is capable of storing all connectivity information in (links + streets) cells.

Each network link or node may be tagged with four class codes. By using this feature, the program easily partitions the network (for example, by jurisdiction or by street type) for purposes of input, mode-split processing, or display of results. Other input data include coordinates, terminal capacities, impedances, demand data in various guises, scaling factors, program controls, and model parameters.

The first time a network is used, input is in the form of a card-image file. After structural changes have been made in the course of running the program, the required intermediate networks are saved in an equivalent binary format. The final modified network of one planning session then becomes the input to a later session.

Tree Builder

The tree builder uses a variation of the Moore-Dijkstra minimal path algorithm (1), which makes the process suitable for allocating resources over networks subject to capacity constraints. The process builds on one impedance variable and accumulates three others, and in addition optionally applies link access-egress times, terminal times, behavioral factors, and transit waiting times. The expected wait time is computed from transit service data by means of the Dial-Loubal non-line-specific waiting-time algorithm originally developed for inclusion in the Urban Transportation Planning System of the Urban Mass Transportation Administration (UMTA) (2).

Trees are built simultaneously or iteratively. Simultaneous building from several root (sink) points produces nonoverlapping drainage areas. Iterative building processes root points in succession, reaching all network links with each tree. This logic is mandatory whenever trip distribution is performed.

Demand Acquisition

Trip-related data may be input either as trip tables or as trip ends. When several purposes represented in the trip-table input are to be assigned, the user selects the order in which the tables are accessed and the trips are assigned.

Alternatively, trip productions and attractions are accepted by a procedure that proportions P's to A's or A's to P's as the user may desire according to the basic distribution formula

$$T_{ij} = (A_j f_{ij} P_i) / \left(\sum_k f_{kj} P_k \right) \quad (1)$$

where

T_{ij} = trips from a network point i to point j,
A_j = trip attractions associated with network point j,
f_{ij} = friction factor computed as a function of t_{ij}, where t_{ij} is the path impedance from point j to point i, and
P_i = trip productions associated with network point i.

STREAK accepts friction factors defined by the user (fixed index interval) or assists the user by equating f_{ij} to the expression t_{ij}^{-a}, the exponent of which (a) may be supplied by the user or by the model as a default value.

Assignment

The trip-loading logic is nondestructive, backwards, all-or-nothing assignment. In a mode-split context, the planner can ask the program to assign the trips from either mode (or neither). The trips can be loaded conventionally onto nodes identified as zone centroids or directly onto every link within a zone instead of onto a zone centroid. For this latter option, the link loading is done in proportion to length of link in the zone divided by the total zonal link lengths. Specifically, the trip volume on a link is given by the following formula:

$$v_i = (V_j w_i d_i) / \left(\sum_i w_i d_i \right) \quad (2)$$

where

v_i = trips on link i from zone j,
V_j = trips in zone j,
w_i = weight assigned to link i (1.0 unless the user supplies other values), and
d_i = length of portion of link i contained in zone j.

Mode Split

The program can separately save input and result data for two modes and exercise a mode-split process on the calculated total demand based on those data and external factors. STREAK has four built-in mode-split models: multivariate logit, simple logit, elementary step function, and a simple service ratio model. Specifications of model parameters are under the user's control in each case.

Program Commands

By typing just one command on a computer terminal, the analyst sets in motion a chain of planning actions. For example, the command statement

R2ML

will build trees outward from previously designated nodes, distribute demand and perform mode-split calculations, and load demand onto the network.

The program has been kept flexible by triggering much of the operational logic through command statement options. Thus, in the example above, demand assignment would not occur unless the L were keyed in. The command cited, R, has more than 10 options, each with suboptions. Options are usually prespecified by the user, but the program strikes a balance by eliciting suboptions as part of the interactive dialogue.

Program commands fall into five categories. The first controls changes to the network, adding new links, deactivating old ones, creating new zones, and modifying their attributes' values. The second command group affects program parameters, such as the maximum permissible path length, or the index to the vector that contains the control impedances for tree building. The third classification controls planning model execution and is necessarily the most complex in contents and results. The fourth category implements the optional report capability. Input and generated data become displayable in tabular and print-plotted formats. The last set of instructions lets the user reinitialize the current terminal session or end it.

The experienced user has little need for computer prompting. STREAK permits this analyst to specify a series of commands that takes shortcuts through the logic (and dialogue) maze. However, other actions, such as adding new links, always require scrutiny because limits exist on the checks the program can perform for reasonableness. A user's manual has been prepared that describes network coding procedures, program logic, and program commands (3).

Cost of Operation

Different network characteristics and control parameters made it difficult to provide the performance curves for the program. However, in the course of many runs in the Los Angeles South Bay study (4), it was noted (for the CDC Cyber-75 computer) that STREAK could build two 1000-link trees and distribute and assign trips over the total network in less than 3.5 s while testing a large set of constraints. Most interactive commands are processed in fractions of a second although normal time-sharing delay prolongs the response time. In a matter of a few seconds, then, STREAK provides the analyst with influence areas, travel-time contours, service levels, patronage estimates, capacity evaluations, and traffic volumes.

USE OF STREAK

The initial input of data and network description is normally done in the conventional manner with cards or card images. Existing data bases and networks can generally be used as a starting point. A zone system must be overlaid on the network, link lengths must be measured node to node (and by segment within a zone for the optional assignment process), a destination node must be selected in each zone, and zonal trip origins must be determined. If one wishes to use the plot capabilities of STREAK, coordinates must be determined for each node and input to the data base.

After the initial input of data, all data corrections and updates and network modifications are made directly from the terminal keyboard. In addition, it is possible to run partial assignments of one zone or a related set of zones, to examine individual trees, or to perform various other quick tests. By operating in this manner directly from the terminal, the time required to correct the data files, clean up the networks, and calibrate the models is significantly reduced. Calibration of the distribution model generally involves the proper selection of the friction factor exponent to achieve the proper average trip length and total unit distance of vehicle travel for the study area. Calibration of a mode-split model involves the proper selection of time and cost coefficients for each mode.

After development of a clean data base and network and calibration of the models, the planning analysis can begin. In exercising the program, the user can select the entire data base (all zones) or a subset of data or zones of interest. Use of subsets of data and zones permits faster processing and quicker terminal response times and facilitates examination of a large number of alternatives. Examples of planning considerations that can effectively use data subsets are

1. Travel-time contours for site and network alternatives;
2. Population or employment within a given travel time (e.g., 5, 10, or 15 min) of activity centers or other key locations via alternative transportation networks;
3. Maximum time or distance needed to reach a given percentage (e.g., 50 percent of population or employment from various locations for each alternative);
4. Plots of fastest or shortest paths between points in a network; and
5. Determination of catchment areas for candidate sites—transit stations, schools, ambulance locations, and fire stations—and identification of the parts of a region best served by each site so that travel time is minimized.

In comparison with the processing of all zone-to-zone trips for such planning cases, in a time-sharing environment all the needed influence areas, travel-time contours, service levels, patronage estimates, capacity evaluations, and link loadings can be provided in a matter of seconds. An analyst would then keep modifying station locations or spacings, network connections, speeds, frequencies of service, and mode-choice parameters to find improved plan alternatives. By similar modifications, the analyst could perform a sensitivity analysis around any major plan alternative.

In studies that deal with determinations of modal choice or major facility analysis, all zones should be processed. This can also be done on-line, but for large networks it is more economical to print the results off-line on a batch computer. Examples of studies that use zonal subsets and those that use all zones are discussed in the following section.

CURRENT EXPERIENCE WITH STREAK

Experience is growing in the use of STREAK as a planning tool. De Leuw, Cather and Company has used the models in several areas including Boulder, Colorado; Florida's east coast; Los Angeles County; Sacramento, California; Burke Mountain, British Columbia (a new town planned for the vicinity of Vancouver); Parramatta, Australia (a suburb of Sydney); and Melbourne, Australia.

Burke Mountain, British Columbia

The Burke Mountain study illustrates the planning-speed capabilities of STREAK. The computer analysis for this study was accomplished in less than a week. In this study, transportation relations of the proposed new town to the Vancouver region were described in terms of travel-time contours, accessibility measures, and additional highway volumes projected to result from the new development.

Boulder, Colorado

The Boulder study provides a good example of the use of STREAK in its primary role as a sketch-planning tool. Four transit systems were defined and analyzed for the study area: baseline bus, advanced bus, light rail with background bus, and elevated guideway with background bus. The following measures or maps were produced for each alternative:

1. Travel-time (isochron) contours, by highway and transit, for several activity centers and residential areas;
2. Population (or employment) totals within 10, 20, and 30 min of selected locations for various network configurations;
3. Travel time needed to reach 50 percent of the population (or employment) for different locations;
4. Maps of transit/automobile travel-time ratios for several locations;
5. Expected transit waiting times for various destinations from important origin locations; and
6. Forecast patronage of the transit system.

Figures 1 and 2 are taken from the Boulder report (5). The link values were produced on-line, a map was overlaid, and the caption was added to produce the final figures. Note in Figure 2 that the transit/automobile time ratios are high for short trips close to the node being examined. This is a result of the fact that walking plus waiting times for short trips are much larger than automobile times whereas for longer trips walking and waiting times become less significant and the travel-time ratio approaches the inverse operating-speed ratio of the two modes.

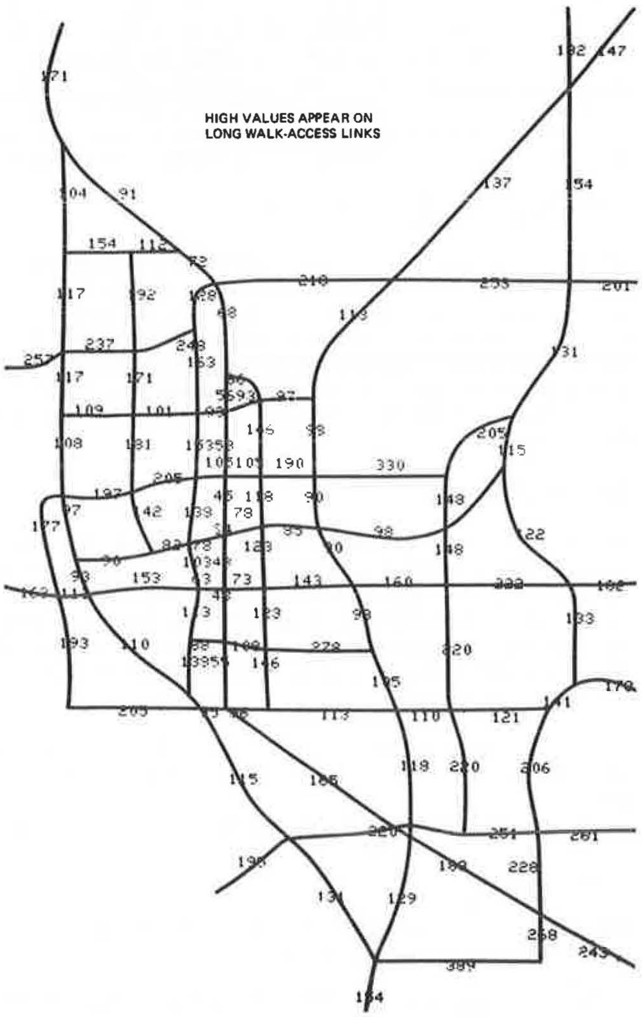
In the Boulder study, interactive capabilities of the model were used to examine a multitude of different configurations in the design of the three proposed transit alternatives. The interactive features were also used at many meetings between the consultant and community staff personnel, elected representatives, and citizen groups.

South Bay, Los Angeles County

The South Bay STREAK analysis in Los Angeles County (4) focused on short- and long-term highway proposals. This study represented a departure from previous STREAK applications in several important aspects:

1. The study area was contained in a large metro-

Figure 1. Use of STREAK in the Boulder transit study: transit access times for node 48 in tenths of a minute.



politan area and consequently experienced a high percentage of external trips.

2. The highway network was much larger than had previously been analyzed with the model.

3. A high degree of detail for the highway assignment was desired for the purpose of analyzing highway improvements as well as network modifications.

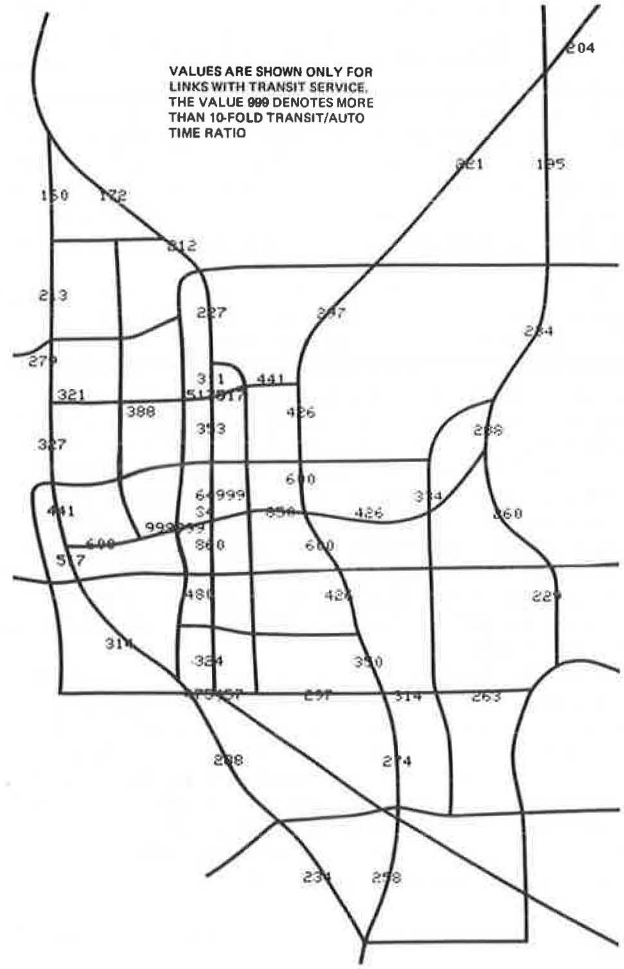
These problems and model demands were successfully met by a combination of model modifications (to handle large networks and more zones) and an innovative methodology for isolating the study area from the rest of the metropolitan region (6). To cope with the highway complexities of the South Bay subregion, the original program was modified to permit the input of detailed networks that contained as many as 1500 links and 150 zones.

To isolate the study area from the rest of the region, the following actions were taken:

1. Future cordon crossings were obtained from a subregional traffic assignment previously prepared by the state of California. These volumes were modified in accordance with more recent demographic and travel forecasts.

2. A buffer area was established between the study area boundary and the cordon line for network analysis. The purpose of the buffer area is to provide a transition

Figure 2. Ratio of transit/automobile times (x 100) for node 48 in the Boulder transit study.



zone from the more detailed STREAK network simulation in the study area to the coarser subregional representation at the cordon line.

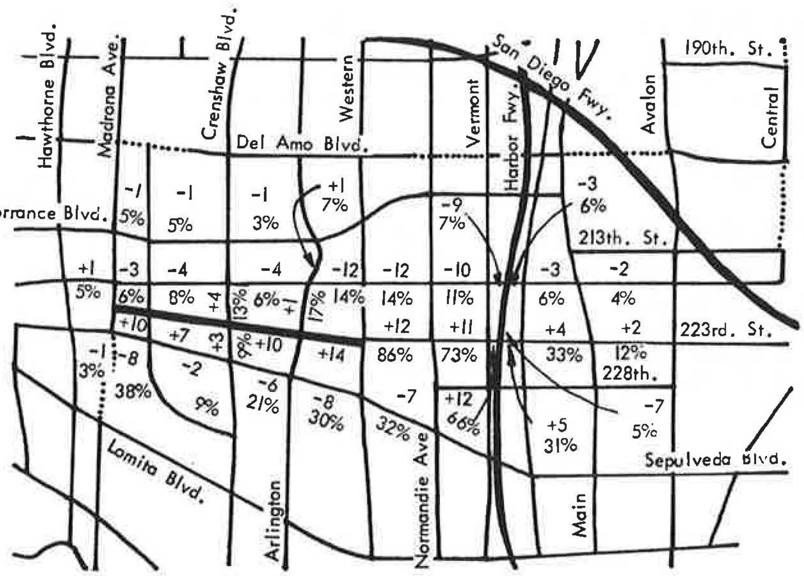
3. Penalties were developed for external trip attractors to represent the composite times and costs of travel outside the study area based on average internal-external trip length.

4. Different procedures were developed for assigning internal trips, internal-to-external trips, and external-to-external trips. The three processes were used in a single assignment by accumulating the link volumes for the three trip types.

Since detailed and accurate highway network volumes were desired, the complete set of zones was assigned during each of the model runs for the highway analysis. However, the interactive capabilities of the model were extensively used in data preparation, network development, model calibration, development of the study area isolation methodology, and development and evaluation of the highway alternatives. In fact, in every step except the final output runs, the interactive capabilities of the model—such as partial assignment, path building, data correction, and network change—were extensively used.

Outputs for the South Bay analysis included simulation of current traffic volumes, forecast 1995 volumes on the existing network, and forecast traffic volumes under various highway improvement alternatives. For ease of comparison, maps were prepared for each of the simu-

Figure 3. Use of STREAK in the Los Angeles South Bay study: traffic impacts of extending 223rd Street to Madrona Avenue.



lated highway alternatives to show the projected volume changes in absolute numbers and percentages. The maps for a given alternative show every link that is projected to experience a change in volume of ≥1000 vehicles/d. Hence, the maps show projected use of the proposed projects, changes in use on nearby facilities, and the total extent of the network impact of the proposal. Figure 3 shows an example of one of the maps from the South Bay study (this figure is redrawn since the original report used a colored basemap). Approximately 100 highway projects were analyzed during this study. Many of these projects were evaluated by means of screenline and volume-capacity analysis, whereas others were subjected to the more extensive analysis shown in the figure. Since the study area was large, an on-line printing of link values would have required five parallel strips of terminal printout paper. Hence, in this study the link values were printed in tabular form and then plotted on maps by hand.

Parramatta, Australia

The study in Parramatta, Australia, involved the analysis of three public transport corridors, each of which has three possible modes and several possible route alignments. STREAK was used to analyze flows toward the regional center—Parramatta. The STREAK network was built to represent all possible combinations of route, mode, station location, and speed. Alternative systems were rapidly analyzed by means of the class code manipulation ability of STREAK. Patronage, mode split, diversion from existing rail lines, average travel times and trip lengths, and trip distribution within the subregion were some of the key characteristics examined by using STREAK. The corridor analysis team used STREAK to evaluate alternative station locations and the effect on patronage of various operational and route constraints. The STREAK exercises were performed over a period of 1 month, and a month was needed for network and data preparation.

Melbourne, Australia

In Melbourne, Australia, the Ministry of Transport has obtained STREAK sketch-planning capabilities. The model has already been used on their strategic zone system, and future applications include investigation of the Melbourne underground, pedestrian movement in the city, and road staging studies.

Another application in Melbourne involved analyzing long-term impacts and construction staging for a complete outer ring freeway system. STREAK was used in conjunction with the De Leuw, Cather transport and land-use interaction model TRANSTEP to evaluate the effects on accessibility, travel time, and road loadings for different construction sequences of the outer ring. Eight selected areas were analyzed in detail, and STREAK provided an indication of how the benefits from each section of the ring were distributed throughout the total metropolitan area. The road network was coded by members of the Melbourne Joint Road Planning Group, who also participated in the STREAK on-line analysis sessions. The total STREAK exercise was completed within 2 months; the analysis was completed in 2 d.

SUMMARY

An interactive computer planning program called STREAK has been used and debugged through application to several studies. When used in its primary role of sketch planning, the planning package has demonstrated advantages of cost and time savings in comparison with conventional batch-loaded planning programs. STREAK also provides ease of data-file correction and network modification, an ability to quickly examine many alternatives, and an ability to respond interactively to a wide variety of planning questions by means of a portable terminal. For the planner who wishes to examine several alternatives on a limited budget or in a short time, STREAK may be a more appropriate tool than the conventional batch-loaded computer program.

STREAK is not a planner's panacea. Although the model currently can handle networks as large as 1500 links, STREAK is not recommended for applications of large highway networks with capacity restraint and iterative assignments. Even in such studies, the model would still provide some advantages in data and network preparation, but most of its other special features, including much of the savings in cost and time, would be rendered useless. However, in sketch planning and in many other planning applications such as those discussed in this paper, STREAK offers several advantages.

In addition to economic and time considerations, many planners will welcome the ability to work directly with the data, the networks, and the alternatives without the intermediary steps of coding, keypunching, computer running, and printout. Instead of taking problems to the computer, perhaps planners should try bringing the computer to their problems.

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Creation of Urban Transportation Network Models From DIME Files

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The development of a set of computer programs that use U.S. Bureau of the Census geographic data to create urban transportation network models is reported. The process uses the Dual Independent Map Encoding (DIME) files created by the U.S. Bureau of the Census for each of the major standard metropolitan statistical areas of the United States. Manual coding of networks is reduced to a minimum, and highly detailed network models can be created. Functioning and use of the program are documented, and the way in which computer graphic displays are readily generated from DIME file data is demonstrated. Examples of computer graphic output from the program are presented.

Transportation planners have long been faced with the problem of analyzing vast amounts of data. Although the use of computers has made data handling easier and advanced mathematical techniques have provided powerful tools to test hypotheses and find underlying structures, the planner still has difficulty in using all the numerical output received through the process. As a result, the planner, working under time constraints and monetary budgets, has less opportunity to analyze alternative plans.

This paper documents the development of a methodology to create models of urban transportation networks from available U.S. census data. The methodology revolves around the use of new computer software to minimize network data collection. In addition, it provides the basis for graphic displays of transportation system planning information.

Much of the transportation planner's task involves analysis of transportation systems such as streets, bus routes, and rail lines. Dealing with these systems numerically often requires creating an abstraction of the system by using graph theory in which street or line segments are represented as links or "edges" and intersections or stations are represented by nodes. Numerical values that represent speed, capacity, distance, and other system characteristics are assigned to each link and node, and this results in a network simulation that can be analyzed by using computerized mathematical models.

MODELING TRANSPORTATION NETWORKS

Modeling a transportation network involves three stages of work. First, one must specify the network to be modeled. This involves making a number of important decisions including (a) the zonal structure or geographic subdivisions of the area being modeled, (b) the scale or level of detail of the model, and (c) the number of elements—links and nodes—to be included in the model. Second, one must prepare the data for machine processing. This includes (a) specifying link characteristics, such as length (distance), time, and capacity; (b) coding the network, which includes numbering nodes and determining nodal x-y coordinates; and (c) preparing the input data cards or records. At this point, the network model is ready for machine processing.

Machine processing of the network model includes several tasks. First, one must create a computer file, or historical record, of the network. Next, zone-to-zone routes through the system, or minimum paths, must be calculated. These files of sequential links and nodes, known as trees or vines, must be stored and verified. Often, manual searching through tables of numerical output is required to see if the computer-generated routes are reasonable and error-free. From these minimum path files, individual link travel times and costs are summed to derive zone-to-zone travel times and costs. Finally, zone-to-zone travel demand is matched to the network to determine the amount of traffic flowing over each route. Other types of network analysis are possible as well, but the procedure outlined above is the one most commonly used.

Two common difficulties have been found in creating and analyzing network models. First, a great deal of information must be collected to supply an adequate representation of a network. Urban areas typically have thousands of streets and hundreds of kilometers of bus lines. A computerized network model may have several thousand links and nodes that require thousands of data items punched on computer cards. This process, known