EMME/2: Interactive Graphic Method for Road and Transit Planning

ANDRÉ BABIN, MICHAEL FLORIAN, LINDA JAMES-LEFEBVRE, AND HEINZ SPIESS

The multimodal equilibrum-equilibre multimodal (EMME/2) system is a multimode urban transportation planning method designed for interactive use. It is more comprehensive than other interactive graphic methods that have been developed to date. It has been developed on the Cyber 173 of the University of Montreal; however, it may easily be adapted for a certain class of micro (or mini) computers. In this paper we describe the general concepts that underlie the design of the EMME/2 system; the structure of its data base; and the possibilities offered by the network editor, the matrix editor, the function editor, the assignment processors, and the modules that produce the results.

During the past 10 years a wide variety of transportation planning methods have become available for various urban and regional applications. Most of these methods have been implemented for use on modern computers in a batch-type environment. Although many successful applications of these methods have been achieved, and the new generation of urban transportation models [such as the Urban Transportation Planning System (UTPS) and Multimodal Equilibrium-Equilibre Multimodal (EMME/1)] go a long way to alleviate the difficulties associated with their behavioral validity and computational efficiency, the dialog with the planner is still rather cumbersome. The transfer of information between person and computer is done via relatively cumbersome procedures, sometimes involving computer analysts who have no interest in planning and are also limited by the management of a given computer installation. The typical situation that requires the use of such computer-based models is the evaluation of future scenarios, which may reflect changes in the road and transit networks or changes in the socioeconomic characteristics of the urban area. Such use requires quick and efficient communication with the computer-based models that evaluate the proposed scenarios.

The approach that has emerged over the past few years, particularly in the context of transit route planning, is to use interactive graphics to enable direct dialog, with real-time graphic or nongraphic response, between the planner and the computer-based planning method. It allows the planner to engage in the planning process by using the terminology that he or she is familiar with and obviates data-processing tasks. Once the data base is set up, the planner need not know or be concerned with the technical details of computer programming or computer systems. It also permits the instantaneous visualization of input data, results of computations, and information retrieved from the data base, all in graphic or list form. EMME/2 is a multimode urban transportation planning method designed for interactive use. It is more comprehensive than other interactive graphic methods that have been developed to date.

GENERAL CONCEPTS THAT UNDERLIE DESIGN OF EMME/2

The data that may be entered, modified, and used for calculations in EMME/2 fall into three main categories: networks, matrices, and functions. Figure 1 gives a schematic representation of the EMME/2 data base and is helpful in clarifying the descriptions that follow.

The network data may be input, modified, and displayed by using the network editor of EMME/2. The

Figure 1. EMME/2 data base.

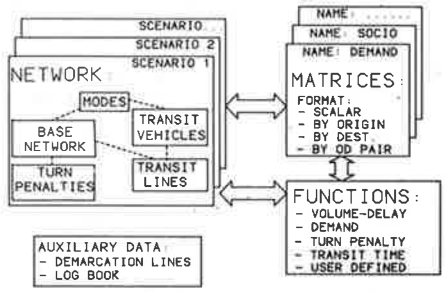
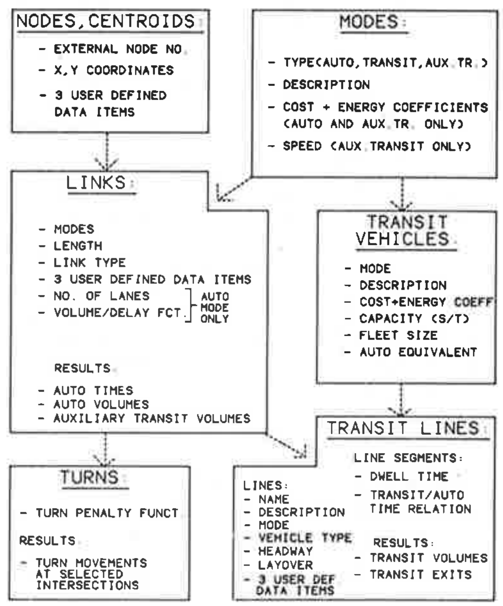


Figure 2. EMME/2 network structure.



matrices of the EMME/2 data base may be entered, modified, and displayed and various matrix calculations may be performed by using the matrix editor. All relevant functions of the EMME/2 data base are entered and evaluated by using the function editor. The EMME/2 data base contains demarcation lines and a log book, which we refer to as the auxiliary data. Demarcation lines may be superimposed on graphic displays to make them more readable and a log book keeps track of the use made of the various EMME/2 modules in manipulating the data base.

Networks

The transportation infrastructure that spans the region studied is represented by a multimodal network. The network descriptors are the modes, base network, transit vehicles, transit lines, and turn penalties. Any of these data may be modified at any time, provided that the hierarchy of the data structure is respected. For example, a transit line cannot use a vehicle type not present in the vehicle table (see Figure 2).

The base network is defined by the list of all nodes, and all the links between those nodes, used by any of the modes. Intersections that are described at the level of detail of turning movements are prepared separately. The turn penalties are indicated only for penalized movements.

The line itinerary is defined as a sequence of nodes. It is not necessary to specify all the nodes along a route. If nodes are omitted, the line is assumed to pass through the nodes on the shortest path between the specified nodes. Dwell time and the transit time function, which correlates the speed of the transit line to that of the automobile mode, need only be specified when their values change. These data are stored by line segment. Up to two layovers are allowed in a line itinerary and they are specified immediately after the nodes where the layover takes place. It is not necessary for a transit line to return to its starting point, such as do certain services during the peak hour. The base network is defined by the unit of all nodes and all the links between those nodes used by any of the nodes.

The user may specify up to three additional data elements for each node, link, and transit line. Such user data may include observed link flows, observed link travel times, or any other data that the planner intends to use in subsequent analyses. Another example would be accident rates at given nodes of the network.

Each complete network data set (modes, base network, transit vehicles, turn penalties, transit lines) makes up a scenario, and the base year is one of these scenarios. The user may define a new scenario by duplicating the data present in an existing scenario and making the appropriate changes in any one of the network data components. All these manipulations may be performed interac- tively, with graphical output, when appropriate. In EMME/2, the network data that correspond to a base year is not conceptually different from that corre- sponding to a future year configuration.

Matrices

The matrices that are handled in EMME/2 may be full matrices, origin or destination vectors, or scalars. These may contain various socioeconomic data related to the zone subdivision of the urban area studied, such as origin-destination demand matrices or origin-destination travel times by mode. A matrix may be both an input to or an output from a computational procedure.

The matrix editor has been designed in a way that permits the user to choose a matrix format appropriate to his or her data in order to avoid duplication of data in the data base. For instance, if a full matrix has the same value in all its cells, then the user may specify a scalar matrix, give the value, and the matrix editor will use only the space required to keep the scalar in the data base. However, when a full matrix is requested in an EMME/2 module, the matrix editor will automatically expand the scalar value to a full matrix with that value in all of its cells within the module at execution time. The same concept applies to given values for origins or destinations.

The matrix editor does not define any matrices by default. The definition of a matrix and its contents are left to the user. Thus, if an assignment routine expects the availability of an origin-destination matrix, the user defines this matrix and ensures that it contains the correct data. This provides great flexibility in evaluating a given scenario that has different origin-destination matrices.

Any network scenario created by the network editor may be used with any of the matrices present in the data base. The user identifies the relevant matrices that he or she wishes for a given scenario. The matrix editor of EMME/2 also contains matrix balancing procedures in two and three dimensions. Their judicious use, with the appropriate matrices, permits a user to scale matrices or to implement some versions of classical spatial interaction models.

Whenever the matrix editor expects a zone number, a zone group can be specified, which indicates that the operation applies to all zones within the group. A zone group is a set of zones. A set of zone grouos that includes all the zones is called an ensemble. Within an ensemble, a zone may be in only one group. The user of the EMME/2 system may specify up to 26 ensembles, each containing up to 100 zone groups. The advantage of using zone groups is that for many applications it is necessary to select subsets of the zones, and the use of zone groups allows this selection to be accomplished efficiently.

The matrix editor includes a module that permits the user to perform matrix calculations. The user specifies the operations that he or she wants to perform as an algebraic expression. Such algebraic

Figure 3. EMME/2 program structure.

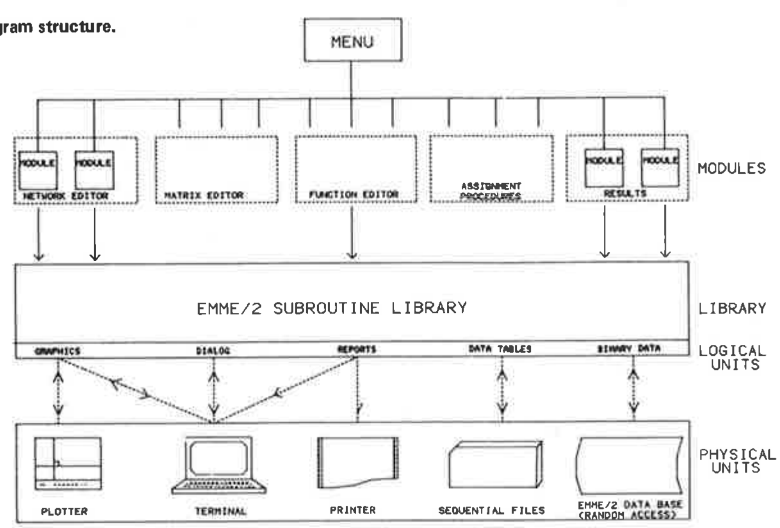


Figure 4. Menu that displays available EMME/2 modules.

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1.  U T I L I T I E S

1.11 DIRECT DATA BASE MANIPULATIONS
1.21 LOG BOOK CONSULTATION
1.22 SCENARIO MANIPULATIONS
1.23 MODIFY TITLES AND UNITS
1.31 I/O FILE MANAGEMENT
1.41 INPUT / MODIFY / DISPLAY DEMARCATION LINES

2.  N E T W O R K   E D I T O R

2.01 INPUT / MODIFY / OUTPUT MODES
2.02 INPUT / MODIFY / OUTPUT TRANSIT VEHICLES
2.11 INPUT BASE NETWORK USING BATCH ENTRY
2.12 INPUT / MODIFY BASE NETWORK INTERACTIVELY
2.13 PLOT     BASE NETWORK
2.14 OUTPUT   BASE NETWORK
2.15 PLOT SHORTEST PATHS ON BASE NETWORK
2.21 INPUT TRANSIT LINES USING BATCH ENTRY
2.22 INPUT / MODIFY TRANSIT LINES INTERACTIVELY
2.23 PLOT     TRANSIT LINES
2.24 OUTPUT   TRANSIT LINES
2.31 INPUT / MODIFY / DISPLAY TURN PENALTIES
2.41 INPUT / MODIFY / DISPLAY USEP DEFINED DATA

3.  M A T R I X   E D I T O R

3.01 INPUT / MODIFY / DISPLAY ZONE GROUPS
3.11 INPUT MATRICES USING BATCH ENTPY
3.12 INPUT / MODIFY MATRICES INTERACTIVELY
3.13 PLOT     MATRICES
3.14 OUTPUT   MATRICES
3.15 COMPARE MATRICES
3.16 PLOT HISTOGRAM OF MATRICES
3.21 MATRIX CALCULATIONS AND BALANCING

4.  F U N C T I O N   E D I T O R

4.11 INPUT FUNCTIONS USING BATCH ENTRY
4.12 INPUT / MODIFY FUNCTIONS INTERACTIVELY
4.13 PLOT    FUNCTIONS
4.14 OUTPUT FUNCTIONS

5.  A S S I G N M E N T   P R O C E D U R E S

5.11 PREPARE SCENARIO FOR ASSIGNMENT
5.21 AUTO     ASSIGNMENT
5.31 TRANSIT ASSIGNMENT
5.41 BIMODAL ASSIGNMENT

6.  R E S U L T S

6.01 RESULT SUMMARY
6.11 LIST     AUTO TIMES AND VOLUMES
6.12 PLOT     AUTO TIMES AND VOLUMES
6.13 COMPARE AUTO TIMES AND VOLUMES
6.14 PLOT AUTO TIMES AND VOLUMES ON INTERSECTIONS
6.15 PLOT SHORTEST PATHS ON AUTO NETWORK
6.21 LIST     TRANSIT VOLUMES
6.22 PLOT     TRANSIT VOLUMES
6.23 COMPARE TRANSIT VOLUMES
6.31 LIST     MODAL SPLIT
6.32 PLOT     MODAL SPLIT
6.33 COMPARE MODAL SPLIT
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expressions may be stated by choosing from 16 logical and algebraic operands and 9 intrinsic functions. The variables that may be used in these expressions are the matrices of the EMME/2 data bank, centroid numbers, and zone groups.

Functions

All the functions that are used in EMME/2, such as volume-delay functions, transit-automobile travel time relationships, turn penalties, and demand functions are specified by the user as algebraic expressions. These functions are not part of the code as user-defined functions or subroutines as in the EMME/1 system or other similar systems. When an EMME/2 module requires the use of a particular function, the function is then evaluated by using the appropriate data that correspond to the variables specified by the user in the algebraic expressions that define these functions.

In addition to the classes of functions described above, the user is free to define and display functions that are not employed in any one of the standard calculations of the EMME/2 system.

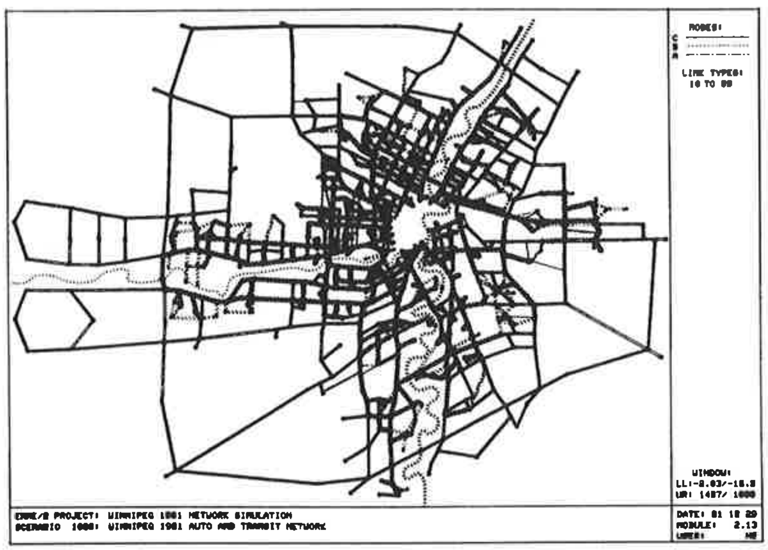


Figure 5. Plot of a multimodal base network shows three modes—C (car), B (bus), and A (access); CBD is not displayed; and two rivers serve as demarcation lines.

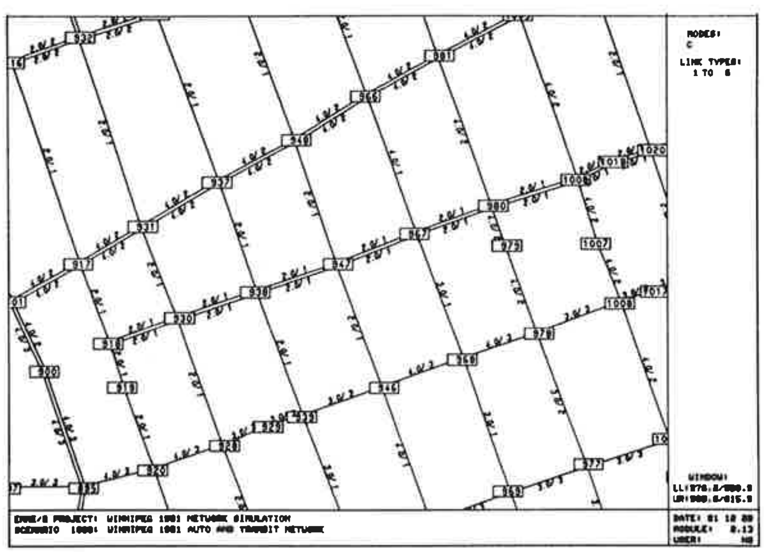


Figure 6. Plotted window of base network displays node numbers and also number of lanes and volume-delay function index for each link.

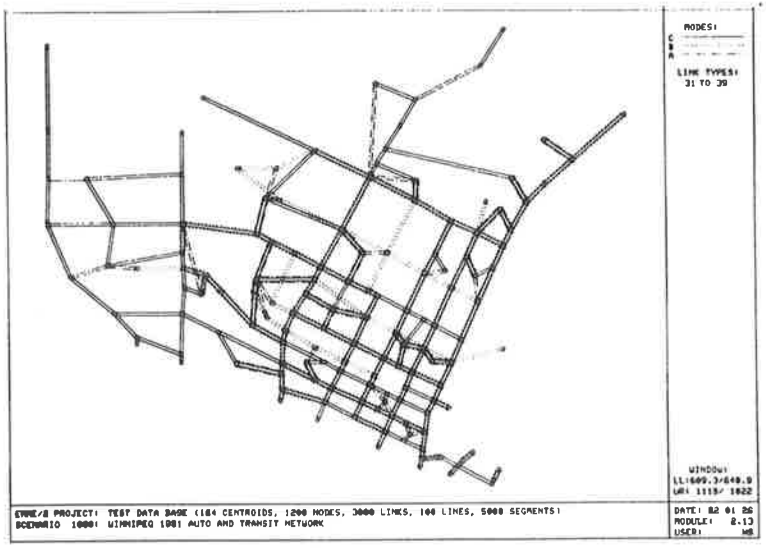


Figure 7. Plot of subnetwork (district 3) of the multimodal base network displayed in Figure 5 is identified by link types 31 to 39.

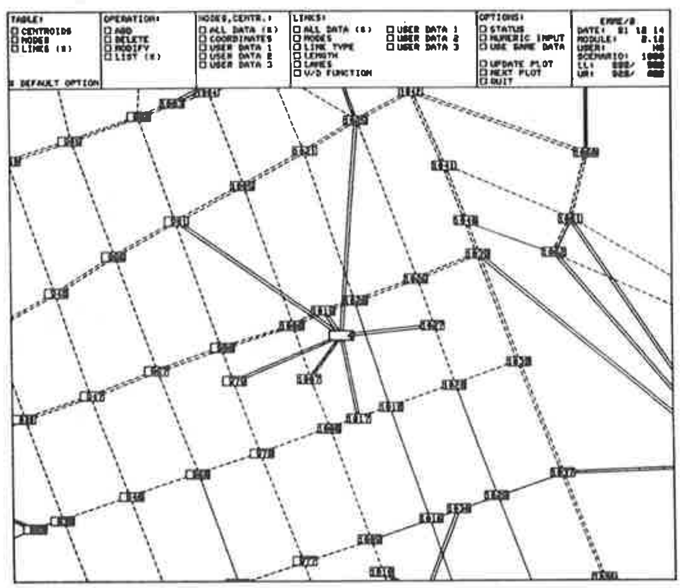


Figure 8. Graphic work sheet used by interactive network editor; window of base network about to be edited is displayed; upper part of graphic work sheet contains command area where user indicates data tables to be modified and operations that will be used in modifications.

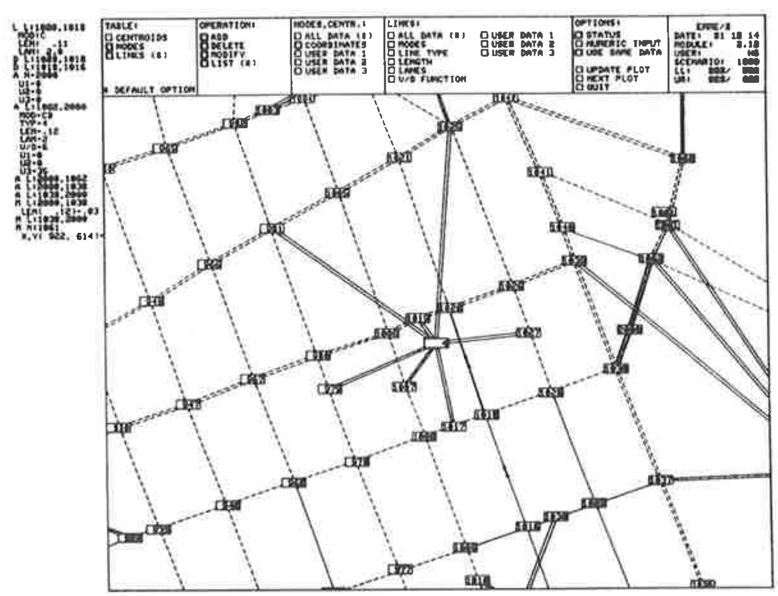


Figure 9. Graphic work sheet after certain modifications of the window in Figure 8 have been carried out; left-hand margin is a pad that records modifications and permits an abbreviated dialog for additions. For instance, the data of link (1020, 1018) were first listed; then links (1020, 1018) and (1018, 1016) were deleted; then node 2000 was added.

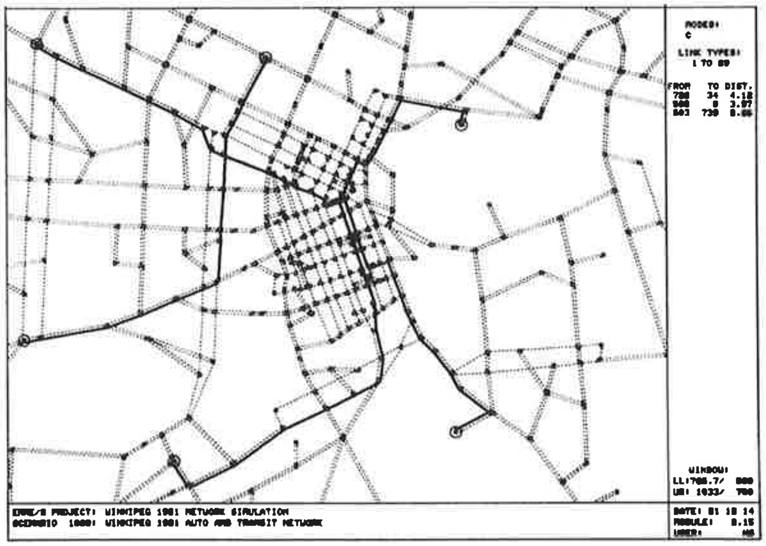


Figure 10. Plot of shortest distance path between two nodes on base network. The two nodes are identified interactively by using cross-hair cursors. The right-hand margin contains from node, to node, and distance in unit length. Shortest path is displayed with a heavy line on the base network.

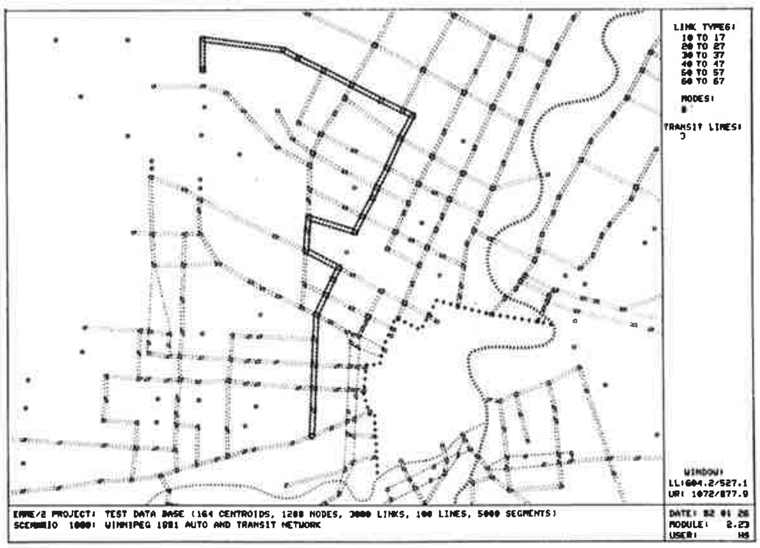


Figure 11. Plot of transit line number 3 on a window of base network that displays only links used by bus (B) mode.

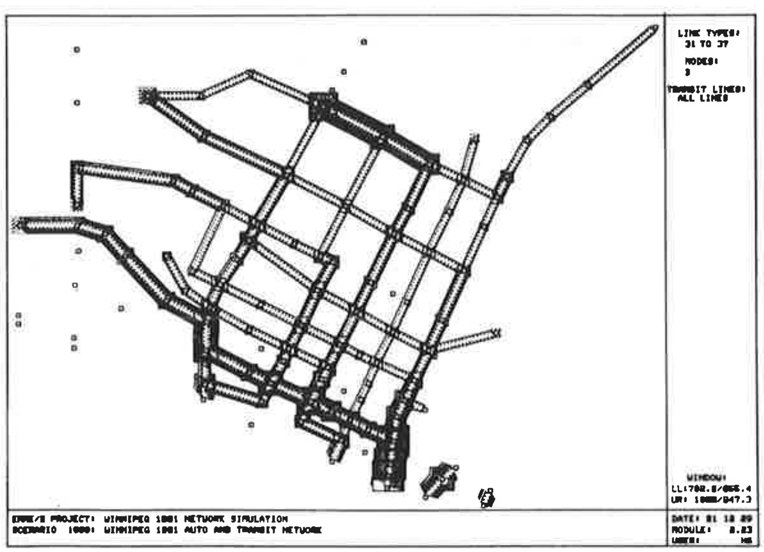


Figure 12. Plot of all transit lines that serve district 3.

Figure 13. Plot of turning movements at selected intersections; forbidden turns are not shown and penalized turns are indexed with the corresponding penalty function.

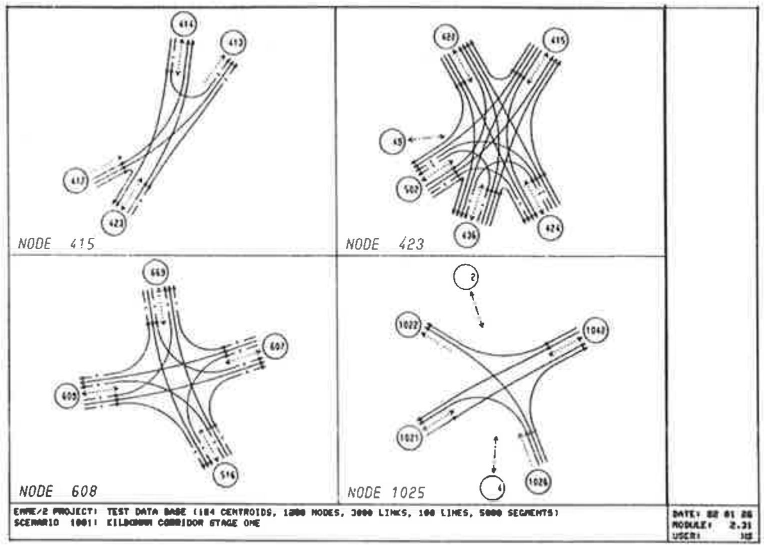


Figure 14. Plot of productions (row totals) and attractions (column totals) of origin-destination matrix; right-hand margin gives scale used for display bars.

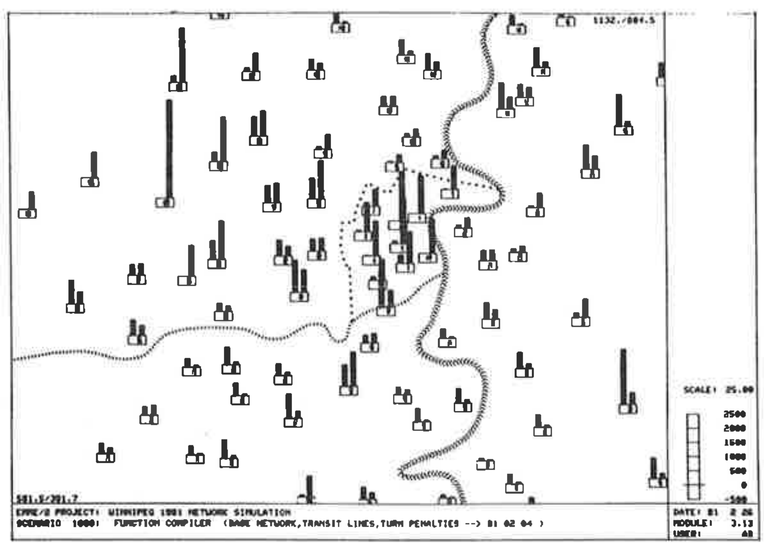
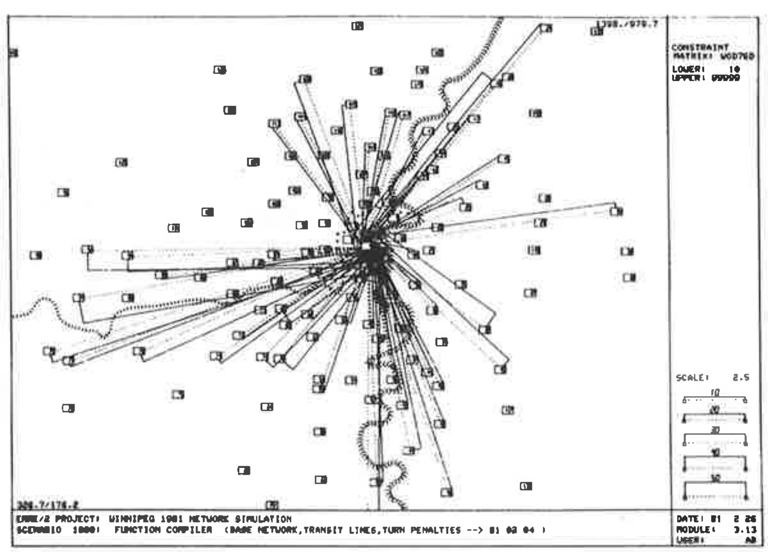


Figure 15. Plot of a column of the origin-destination matrix or desire lines for centroid 4: right-hand margin gives scale used for display bars.



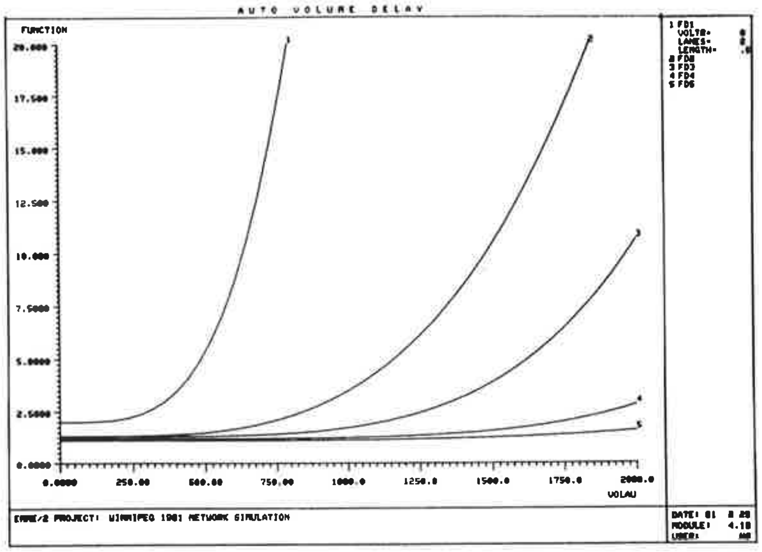


Figure 16. Plot of four volume/delay functions: right-hand margin gives functions plotted (FD1, FD2, . . .) and parameters that were fixed at certain values (VOLTR=0, LANES=2, LENGTH=0.5).

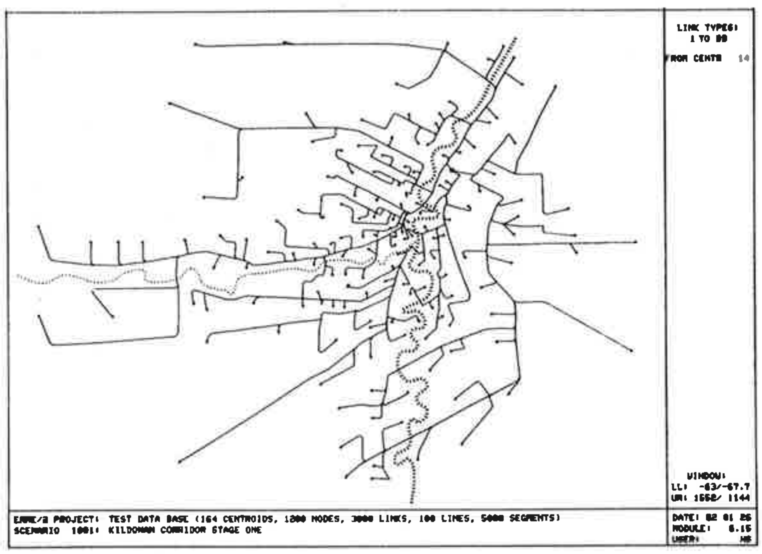


Figure 17. Plot of shortest path tree on automobile network (including penalized turns), based on link times that result from an assignment: right-hand margin gives root of tree, centroid 14.

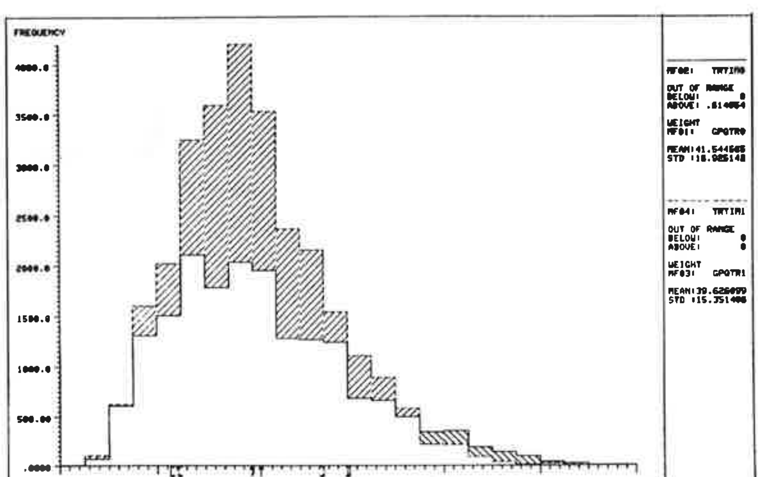


Figure 18. Comparison of two histograms of travel-time distributions: base year corresponds to travel-time matrix TRTIM0 and demand matrix GPQTR0; future scenario corresponds to travel-time matrix TRTIM1 and demand matrix GPQTR1; right-hand margin also contains mean and standard deviation of each distribution.

Figure 19. Plot of automobile link volumes that result from an assignment on automobile network: right-hand margin indicates that volumes smaller than 100 are not plotted (THRESHOLD : LOWER : 100) and scale used for display bar width.

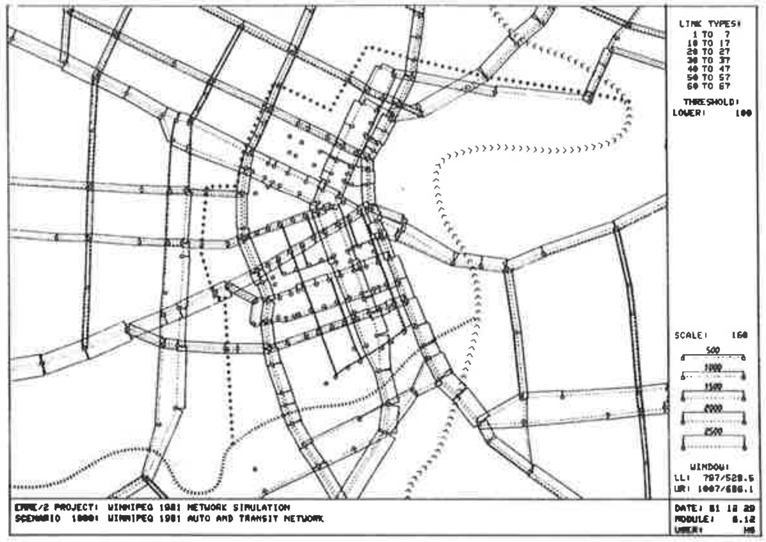


Figure 20. Plot of automobile link speeds as a result of an assignment on the automobile network.

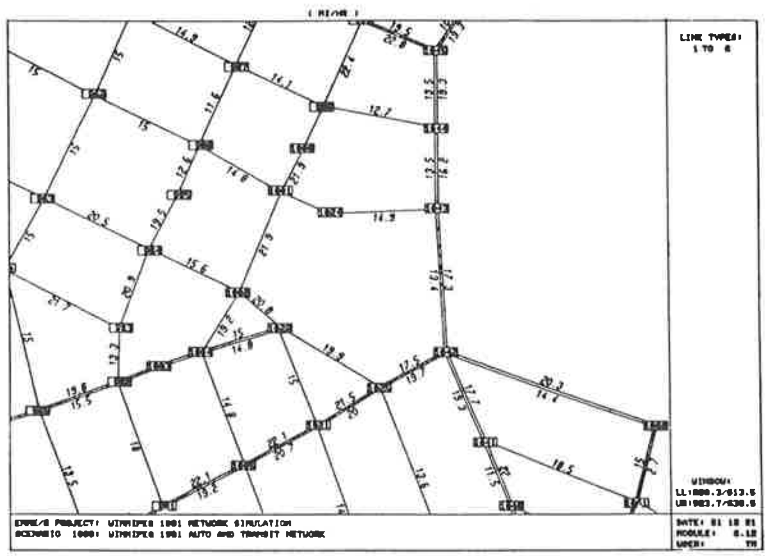
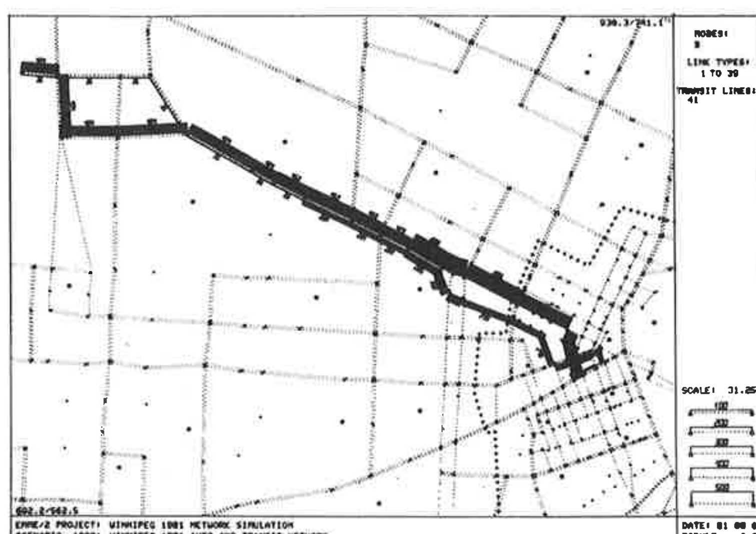


Figure 21. Plot of transit volumes on transit line number 41 as a result of an assignment on transit network.



Assignment Procedures

The most general assignment procedure provided by EMME/2 is a multimodal equilibrium assignment method that has variable demand. It computes the equilibrium demands, flows, and service levels for all the modes considered. Because the assignment procedures have a modular structure, the user may select equilibrium assignment with fixed or variable demand on the road network or variants of shortest path or multipath assignment on the network served by the transit and any or all of the auxiliary transit modes. For variable demand assignment, both mode choice and direct demand functions may be specified.

Results

EMME/2 permits the user to obtain a wide variety of results, both in interactive graphic form and as a printed output. The main feature of the results is interactive comparison of scenarios with accompanying graphical display. Although the main results pertaining to comparison of scenarios are related to link flows, origin-destination demands, and service levels, a wide variety of other results may be obtained by using the user-defined data (e.g., comparison of predicted versus observed flows for calibration).

Worthy of emphasis is that, unlike a batch code, where each successful execution terminates with a particular set of results, an interactive graphic code permits the user to obtain results of different types during a particular EMME/2 session. The notion of result is thus different from that of a batch code and may be considered to consist of the entire gamut of displays, results of computational procedures, data bank queries, and scenario comparisons.

Demarcation Lines and Log Book

For a given urban area the user may define demarcation lines that may be superimposed on a graphical output that covers the area spanned by the zone subdivisions. A demarcation line may identify geographical characteristics of the urban area, such as rivers or mountains or certain regions of the city, such as the central business district.

An automatic log book keeps record of the identity of the user and of the modules and elements of the data base used during all EMME/2 sessions.

EMME/2--THE COMPUTER-BASED SYSTEM

EMME/2 has been coded in standard ANSI Fortran IV and has been designed for easy transferability to various computer makes. It has been developed on the Cyber 173 of the University of Montreal; however, it may be adapted easily for other computers, including a certain class of mini or micro computers.

The EMME/2 code has a modular structure. Each of the modules is an independent program but all the modules share the EMME/2 subroutine library. All data transfers between modules occur only via the data base. Figure 3 gives a schematic representation of the program structure.

At present, EMME/2 is implemented for use on any of the Tektronix 4010 and 4110 series of terminals. Any output displayed on the screen may be copied by using the Tektronix 4631 hard copy unit. The same output may be drawn with a high technical quality by using the Tektronix 4663 digital plotter, when available. EMME/2 may be easily adapted for use with other graphic equipment of comparable resolution.

SOME OUTPUT EXAMPLES OF EMME/2

Figures 4-21 are a sample of the kind of output that is made possible by the EMME/2 system.

Jeffries Freeway Corridor Transit Design Project by Using the IGTD System

LUSIA DENDE GALLIO AND JAMES MASLANKA

This report presents the findings of an experiment in designing bus routes in a regional freeway corridor by using the Interactive Graphic Transit Design System (IGTDS). This project was conducted by the Southeastern Michigan Transportation Authority (SEMTA) in cooperation with the General Motors Transportation Systems Center. As a modeling tool, IGTDS allows the transit planner to study the alternatives and variables of a transit problem in spatial terms. The advantage of the IGTDS program is that it is easy to operate because it was designed for use by persons who have little or no computer background. Several objectives were realized by undertaking this corridor demonstration project. First, SEMTA transit planners were given an opportunity to work with and evaluate the latest computer graphics technology. Second, the IGTDS model was tested in terms of a real world transit planning situation by using existing data. Finally, the IGTDS method was compared with conventional transit planning methods in order to determine the strengths and weaknesses of each technique. This report describes and documents the IGTDS transit design process. It covers the areas of data development, operational characteristics, and alternatives analysis. Problems associated with each of the various steps are discussed. A primary part of the documentation of this experiment is a comparison of the effort involved in solving transit planning design problems by using IGTDS or conventional transit planning methods. Conclusions and recommendations are stated regarding the use of IGTDS as a feasible planning tool.

In June 1979 General Motors contacted the Southeastern Michigan Transportation Authority (SEMTA) pursuant to a proposal for a joint analysis involving Interactive Graphic Transit Design System (IGTDS) 2. IGTDS 2 is the second, advanced version of the transit design system. An agreement was reached and the responsibilities of both parties were delineated. SEMTA was to provide the experimental design, demand by census tract, network modifications, staff time, and preparation of the final report. Training on the use of IGTDS 2, computer time, the existing Detroit transportation node and link data base, and the technical support for allocating census tract