INTRANS AND BROWSE: AN INTERACTIVE GRAPHICS SYSTEM FOR PLANNING RELATED DATA ANALYSIS

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This paper describes the Interactive Transportation Analysis System (INTRANS). INTRANS is a man-computer interactive graphics system designed to serve transportation and urban planners. Currently, INTRANS is being used mainly for analysis of spatial data. Its major use in the future will be as a skeleton for interactive planning models. INTRANS operates in the Computer Center of the University of Illinois at Chicago. It uses an IBM 370 as the central processor. The paper defines the need for interactive graphics in planning, the areas where its use is likely to be effective, and the major problems in its implementation and use. It then describes the design of INTRANS, its major elements, and how the system as a whole is being used. The paper concludes with a description of plans for development for both the short term and the long term.

•DURING the last 2 decades, a new type of sociotechnological planning process has emerged. It was initiated in the mid-1950s with the urban transportation planning process (1); during the 1960s, it was spread to various urban growth and activity allocation models [e.g., Boyce and Day (2)]. Currently, this type of planning process is applied to other urban subsystems as well as in other related areas.

This process is characterized by the set of tools that are inherent in its application. These tools are called here, in aggregate, the data-models-computer (DMC) system. Large volumes of data are collected and produced by the planning process. These data are used as a basis for a detailed quantitative description of the region. The data are analyzed by a set of mathematical models including prediction, cost, and network analysis models.

The handling of data as well as the calibration and application of the models is possible only through the use of computers. As a matter of fact, specific analysis procedures have always been designed by considering the limitations of available computers and have been improved with advances in computer technology.

The DMC system has been continually growing and improving with increased volumes of data and better models and computers. Its potential to supply knowledge on our environment and to support planning activities is quite large. However, the utility of the DMC system is curtailed by the difficulties in communications between it and the human users. Improving communication and interaction between people and the DMC system is a most cost-effective step in the current state of affairs.

CHARACTERISTICS OF INTERACTIVE GRAPHICS SYSTEMS

A promising way to improve man-DMC communications is by the use of man-computer interactive graphics systems (IGS). In these systems, the user and the computer communicate in real time; a large part of the information transfer is done graphically through a cathode ray tube. In this paper, the development and performance of such a system are described.

A number of advantages of IGS are obvious. Most important is the significant reduction in time consumption. Real-time interaction cuts the overhead time spent in punching cards, submitting a job, and waiting for the output to return. Graphic displays enable perception and comprehension of information much faster than do other methods; this is particularly true in spatial analysis where both the intensity relationships and the locational relationships between variables are important. Direct access to the computer enables one to assign to it a large number of relatively small tasks that otherwise would be done manually. It also enables immediate access to large amounts of data and various model programs that are stored in the computer and its peripheral equipment.

Potential Uses of IGS in Planning

Access to Information—Because of its characteristics, IGS might be used effectively in many phases of the planning process. Easy access to large amounts of information may enable planners and model builders to examine raw data and final, as well as intermediate, outputs of various models much more thoroughly than currently feasible. This may result in a significant reduction of errors, better understanding of the models, model improvements, more realistic assessment of their limitations, and reliability of model outputs.

No less important is the potential use of IGS in presentations to the general public and to decision-makers. Easy access to large amounts of information (and, possibly, models) will enable proper immediate response to a wide range of inquiries and the development of meaningful and factual discussions in many, possibly unexpected, directions. This will be a significant improvement on the existing situation where presentations are limited to material that is fully prepared beforehand.

IGS can be used effectively to access a "bank" of base information on a region. Such information could be stored permanently on the IGS files and then retrieved in response to users' requests. Flexibility in choosing the format and content of the retrieved information and hard copy capabilities, which are usually available, are very useful for this purpose. Using IGS in this framework can substantially increase the quality and speed with which planning agencies can respond to information requests, both internal and external.

Editing—Another potential application of IGS is in data editing, particularly in cases where human judgment is required in the editing and where graphical display of the stored information might be of help. Such a case is, for example, the editing of coded networks (5). Here, the required record keeping, cross references, and routine calculations can be done by the computer, relieving the analyst of these error-prone activities. This is additional to the advantage of being able to observe graphically the parts of the network that are of interest, in the manner in which they are coded.

Interactive Planning and Design—A family of applications in which IGS seems to have a large potential is in plan formulation, plan modification, and design. Here, the sophistication of the systems can vary significantly. In one extreme, IGS can be used as an editor, enabling easy storage, retrieval, and changes in plan details and not much more. Systems could be somewhat more sophisticated, where, through the use of various cost and prediction models, they would supply the analyst with estimates of required resources and impacts of alternative plans. They may also make routine calculations and fill standard details. At the other extreme, interactive graphics planning systems may be quite sophisticated. By using programming techniques, they may find optimal plans, in response to the analyst's specification of the solution space, the constraints, and the objective function. In this field of applications, IGS seems to be most useful in sketch planning where rough examination of many alternatives is required and in introducing and analyzing small-scale local improvements in an existing plan where the marginal impacts can be estimated by simple models without reanalyzing the whole plan.

Difficulties in Use of IGS

The list of potential uses can be made much longer. However, there are a number of constraints on the effective use of IGS that strongly limits its applicability. Some of the constraints are inherent in the characteristics of IGS and human users; others are temporary and likely to be relieved in the future. The constraints are due to the characteristics of the human analyst, available computer technology, the type of problems in transportation planning, and the institutional structure of planning activities.

First, the large power of IGS and the interactive environment impose a high load on the analyst using them. The rate of information being transferred to the analyst and the rate of decisions that he has to make increase significantly. Effective use of IGS will strongly depend on how well it will be adapted to human constraints. For example, to make the use of IGS easy, the user would tend to make his commands simple. At the same time, in order to maximize user control of the IGS operation, a large set of commands, hence a complicated command structure, is necessary. This trade-off between simplicity and flexibility is only one of the difficult but necessary decisions that have to be made in order to make IGS best fit human characteristics. It is likely that new planning strategies, new techniques, and special training will be required before IGS can be implemented effectively. Only actual experience can point out optimal IGS designs.

Constraints due to computer technology are numerous. First, IGS demands, by definition, a short response time (maximum of a minute or so). If we consider the speed of available computers, this limitation excludes a large number of problems and existing models. It is likely that many models will have to be reformulated (e.g., by using marginal analyses) in order to be used by IGS. The need for fast "number crunching" and access to large data files implies the need for large computers. At the same time, special technical needs of IGS cause difficulties in running these jobs in a multiple-job environment typical to large computers. Some of these problems can be solved by dedicating full installations (on a full- or part-time basis) to planning IGS. (This has been done by Design IGS, being used in the automobile and aerospace industries.) However, transportation planning is currently being done by many separate, small- or medium-sized agencies using different computing facilities.

Good cost-effective solutions to these problems are yet to be found. However, continual improvements in computer technology allow many of the problems to diminish quickly with time.

The nature of activities in transportation planning imposes some limitations on IGS applicability. Many of the activities in the planning process are not repetitive or are repeated very infrequently. This implies that activity-specific computer programs will not be used very frequently. Because the overhead in designing and implementing any IGS is quite high, it might not be cost effective. No less difficult a problem is the fact that many of the activities in transportation planning have not been standardized yet. They differ significantly from place to place and from problem to problem and are being modified continuously. This implies that it will be difficult, if not impossible, to implement a general transportation planning IGS. In a number of problems where there is standardization, e.g., geometric design, these problems are less serious. [Such a system was designed by Beilfuss, Dwyer, and Phillips (4).] With increased standardization in the field, e.g., the BPR system (6) and the HUD transit package now under extensive development, these problems might be diminished but are unlikely to vanish.

In the following paragraphs, the development and performance of an IGS, called the Interactive Transportation Analysis System (INTRANS), is described. Many of the considerations described affected the design and implementation of INTRANS. In the description, points where trade-offs had to be made are specified, and the reasons for the specific decisions are presented.

DESIGN AND IMPLEMENTATION OF INTRANS

The Computer System

At the very start of the project, it has become clear that the scope of INTRANS will depend strongly on the available computer system. More than that, the resources available to this project preclude any substantial investments in computer hardware. Thus, the problem for this project has been to find the most powerful yet accessible computer and design the IGS around it.

The system that has been chosen is an IGS developed by the computer center at UICC. The system is shown in Figure 1. This system, together with the available software, has the following characteristics.

1. Calculations, data storage, and data management are done by the IBM/370 under OS. This enables access to most of the equipment around it, in particular, disk packs for data and program storage. It also enables the use of the full capacity, power, and speed of the 370 CPU and core memory.
2. The computer system provides for the use of many higher level programming languages, as well as many of the available library programs.
3. The IBM 1800, with the Channel, is used as a controller for fast data transfer. Its potential use as an auxiliary processor has been recognized but not yet implemented. Alternatively, its existing functions can be performed by less "intelligent" and much cheaper devices. (It is expected that by mid-1973 INTRANS will operate through standard high-speed time-sharing communication devices, with no need for the 1800 computer.)
4. The Tektronix storage display tube has a screen measuring 16 x 22 cm. It does not enable dynamic images to be displayed (as is possible with some other display tubes). This limitation pays off in a much lower hardware cost, lower load on the computer during display, and higher resolution.
5. The basic software for communication between the Tektronix and the 370 includes Plotter-type commands for creating graphic displays and routines for two-way transfer of character strings. All these routines can be called by FORTRAN.
6. The system operates under TSO (time sharing). This ensures that, while the user "scratches his head," the load on the 370 is minimal. The option to operate in batch mode (where the program resides permanently in core) is available. It might be useful for smaller computers or in especially large problems. This attribute substantially decreases the cost and operating difficulties of INTRANS as compared to similar IGSs.
7. Currently, the user communicates with the program through a keyboard. A joy stick with a cursor is being added to the system for efficient graphic input.

System Design

Given the capabilities of the computer system and the need for and problems in using IGS in transportation planning, the desired characteristics of INTRANS can be specified.

Real-World Applicability—The capabilities of the available computer system seem to be large enough to enable the use of INTRANS in relatively large problems. Thus, the development of features that might have immediate applications in full-scale, real-world problems has been stressed.

A System—Not a Model—INTRANS has been designed as a system that can support a large set of interactive graphics models rather than as one specific model. This has been done to enable easy adaptability to the wide range of planning applications, to study man-IGS interaction characteristics in simple applications, and to enable continual growth with increased experience. INTRANS consists of the elements that must be included in any planning-oriented IGS. Each separate model is written using the elements of INTRANS, thus ensuring relatively easy future aggregation with other models.

INTRANS is designed to include the elements that are most difficult to program. Thus, adaptation of specific models can be done by people without advanced knowledge in computer programming.

BROWSE—A Model for Data Analysis—A natural first step in developing a planning IGS seemed to be a model for interactive analysis of existing data. A model called BROWSE has been developed for this purpose. It consists of the basic elements of INTRANS with minimal additions. Besides being used for the many needs of data analysis, BROWSE may be used to study characteristics of man-IGS interaction and to evaluate the outputs of other interactive models that will be implemented in the future.

Elements and Structure of INTRANS

When we consider the general type of problems that INTRANS is likely to be used for, the programming problems, and the requirements specified, it becomes apparent that INTRANS has been designed in detail. The major elements in the system are shown in the lower part of Figure 2. In the design of each of these elements, there is a compromise among the consideration of simplicity, minimal core, speed, flexibility, and generality. The following sections discuss the elements in detail. Only experience will show whether the options chosen are the right ones.

Geographic Identification Methods

A major decision in performing spatial analyses is how locations are to be defined and identified. This decision has implications for the structure of data files as well as for details in the logic of many computer programs. INTRANS is an analysis system intended to be used in many different areas and for many different problems. Thus, it should use a specific identification method rather than a unique system to which data management and program logic will be adapted.

Geographical identification is needed for points (e.g., location of a road intersection or a school) and for areas. For points, it is required that any point in the area be identified uniquely. The most widely used method is the Cartesian coordinate system. More than that, this is the method used in the existing interactive computer software. Thus, it has been adopted by INTRANS as the only reasonable choice.

For areas, it is required that the whole region be subdivided into mutually exclusive and conclusive analysis subregions, called zones, and that each zone be identified uniquely. The two major alternative methods are a general system and a grid. In the general system, boundaries of zones, their size, and their shape are specified at will, usually by considering the needs of the analysis; zones are identified nominally. In the grid method, grid squares are considered to be zones. By choosing an origin, direction, and scale for the grid, the exact boundaries of each zone are fixed. Zone identification number can be easily related to its location.

After these alternatives are compared, the choice has been to use a grid system. Following are the major factors that affected the choice.

Simplicity and Economy—In using a grid, much information is available on a zone if its number is known. This includes location of centroid, boundaries, adjacent zones, and area. The coding, storage, and analysis of this information in the general system are expensive in manpower, core, and computer time.

Display Clarity—When a grid is used, the density of zone centroids is uniform. This enables the creation of effective displays of areal distributions by relating the amount of light in each grid to the intensity of the corresponding variable, for example, by using different characters on a "gray scale." (See, for example, SYMAP.) When the general system is used, the distribution of light intensity depends largely on the areas of zones (or distance between centroids).

Data Availability and Use by Planning Agencies—In general, the many agencies that collect and analyze data use different and noncompatible areal units, e.g., census tracts, zip codes, communities, towns and cities, and school districts. From this point of view, there is an advantage to the general system. However, when this factor is considered, it should be noted that many planning agencies, including those in the Chicago region, use a grid as a basis for zone definition.

Efficiency in Analysis—The major drawback in use of a grid system is its inefficiency in analysis. In the general system, it is possible to relate zone sizes to analysis needs, defining small zones only where details are needed. In this way, it is possible to get the required level of detail without a substantial increase in the amount of calculations. This freedom is not available in the grid system.

After all these factors were weighed, it has been judged that the advantages of the grid system outweigh the disadvantages. It is possible to use INTRANS for many problems where a general areal ID system is used. However, in general, this might require special adaptation, and it does not give all the capabilities available to the grid user.

DATA MANAGEMENT SYSTEMS

The important function of the data management system (DMS) in INTRANS cannot be overstressed (3). First, compatibility between various models depends largely on compatibility in data handling. Second, INTRANS is intended to handle large amounts of data. The efficiency and speed of the system depend largely on the efficiency of the I/O operations. A third reason for the importance of the data system in INTRANS is the need for advanced programming techniques. FORTRAN is quite inefficient in terms of core in its nonstandard I/O codes when compared to what can be done in machine-oriented languages. Thus, it is important to relieve the application programmer from the need to program this element.

Functional Organization of the Data

The Study Area—This is the major element in the structure of DMS. Most of the likely analyses by INTRANS will be done on one study area at a time. A study area is represented by a grid of given dimensions (NCOL by NROW) and a given scale (size of a grid). Each INTRANS data set refers to one such study area.

Files—Each study area includes one or more files. Each file stores a cross-sectional picture of the area. For example, different files might relate to different years; alternatively, files might relate to different alternative plans. It is possible to specify summary files that include variables of each of the separate files.

Variables—Each file consists of a number of variables. Variables in different files might have identical names. This is quite efficient for making the individual programs file-independent. Each variable consists of a number of elements; it is possible that different variables within a file have different numbers of elements. A variable might be, for example, population. Each element gives the population in one of the zones. Similar to most variables currently used, this variable has NZONE elements. However, another variable, say trip length distribution, might have a different number of elements. I/O operations are done on the level of variables; i.e., all the elements of a variable are stored and retrieved simultaneously.

Technical Details

DMS uses the structure of partitioned data sets. Each study area is one data set; each variable is a member. Each variable, as well as the data sets, can be labeled with up to 56 characters. Labels are stored in the data set directory. Variables are stored in binary form; they are retrieved directly into the required location without intermediate buffering. There are practically no limitations to the number of variables that can be stored.

DMS programs are used off-line for creation and maintenance of data sets. During interaction, the user can access these programs in order to create or delete variables. The display and compute routines, as well as other models, use DMS programs to retrieve and store variables.

DISPLAY ROUTINES

The quality of the interactive system being constructed depends, to a large extent, on the quality of displays it can produce. The clearer the displays are, the easier it will be for the user to perceive the information they contain. This will determine both the efficiency and the utility of the system.

Good displays are especially important if the system is to be used to transfer information to nontechnicians. In this case, the system will not be usable unless the displays are easily understood. They should be understood even by people who do not have advanced training or experience with the system. (It is not intended that nontechnicians will actually operate INTRANS with no training. However, they should be able to get clear answers to inquiries given to an operator.)

Thus, INTRANS includes the capability to create many types of displays and to closely control the design of these displays.

Types of Displays

The following types of display are available in INTRANS (Appendix).

Map—Maps displaying the areal distribution of intensity of zonal variables (on a grid) can be produced. This type includes three options:

1. Triangles on a 10 x 15 grid with a triangle whose side is proportional to the intensity of the displayed variable in the center of each grid,
2. Numbers on a 10 x 15 grid with one or two 3-digit numbers showing the intensity of the variable(s) within each grid, and

3. Symbols on a 40 × 60 grid with the intensity of variables in each grid described by a character as in SYMAP.

Symbols are used mostly for describing general trends in an area, whereas triangles and numbers "zoom in" for further details. The user can overlay the display with any of a number of precoded maps, showing locations or networks or both.

Distribution—Distributions display frequency or accumulative distribution of variables.

Function—Functions display functional relationship between two variables.

Distributions and functions can be described as a scattered diagram, polygon, step function, or column diagram. As an option, the user may get basic statistics (means, totals, correlations, regression lines) of the variables being displayed.

Controlling the Display Design

The display programs are called by the display command. Display command can be input either by the interactive user or by FORTRAN routines. By specifying the value of control variables, the user can specify the type of display, group, transform, scale, and bound of the displayed variables and thus control in detail the display design. Alternatively, the user can use very short commands, leaving the design of the display to the program.

THE INTERPRETER

The function of the interpreter is to accept user inputs from the keyboard (in the future, also from a joy stick) and change them into numbers that are used as values or addresses by the other programs.

The sophistication of an interpreter increases with the amount of flexibility given to the user. In a highly flexible system (e.g., interpretive languages), the interpreter should be very powerful, enabling the user to give almost any instruction he wants. In a more restrictive environment, the user has very few options, mostly requesting that certain routines be called. In such an environment, the interpreter is quite simple.

In INTRANS, the general tendency is toward a relatively restrictive environment. However, the interpreter that has been implemented is relatively flexible. This may even be some "overdesign."

The main reason for the designed flexibility is that INTRANS is a general system rather than a specific model. The interpreter is intended to serve almost any requirement by a specific model that is yet unspecified. It seems preferable to add some slack now, rather than be forced later to introduce additions that will probably cause incompatibilities.

Another reason for the relative flexiblity of the interpreter is that it was designed to answer the needs of the display routines in the BROWSE mode. It is not likely that many other models will give the user so much flexibility as is required for this specific application.

The interpreter is called by the main model program. It accepts a string of characters, which is called "command" from the user. The interpreter breaks a command into words and checks them for validity. Valid command words cause the interpreter to assign specific numbers to specific locations in an array. A nonvalid command word causes the command to be rejected. The application programmer is able to specify the command words, put constraint on their order, and specify the form in which the interpreted command will be transferred to his program's control.

The interpreter is capable of handling prespecified command words, free-format numbers, and names.

THE COMPUTATION COMMANDS

The computation commands are intended to give the interactive user the ability to formulate and perform computational procedures during interaction. It is expected that most of the procedures will be precoded as subroutines, and the user will have only to choose among them. The computation routines are intended to be used in the few cases where this extra capability is needed.

For example, consider analysis of data on zonal population and land use for a number of years. The analyst might be interested in seeing things like percentage of population increase, net and gross densities, intrazonal relations among various land uses, etc.

It will be practically impossible to precompute or code the routines to compute all the possible combinations. Using the computation command, the user can directly ask exactly what he is interested in.

A second example might be in evaluation. A user might be interested in formulating various measures of performance or weighing schemes. In many cases, it is much simpler to specify the measures during analysis rather than precode all the possible formulations. A typical computation command may look like

DDEN = POP1/RESA1 - POP2/RESA2

This calculates the net residential densities for two cases and the difference between them. The difference is stored in the variable DDEN for further reference. The computation commands use their own interpreter.

OTHER ELEMENTS IN INTRANS

Utility Commands

A number of utility commands are included in INTRANS and are directly available to any specific models. For example, SHOW DIRECTORY lists all the variable names in the data set, together with their labels; SHOW MENU displays all the valid command words. A data editor that enables the user to list and change variables and elements is also available.

Support Procedures

A number of batch processing routines are available for INTRANS users. First, there are programs for data maintenance and program library maintenance. Second, there are FORTRAN batch processing programs that simulate the interpreter and display routines. These programs are used in the debugging of new models. Third, there is a time-sharing version of INTRANS without graphic displays. It is accessible from remote terminals.

USING INTRANS FOR AN INTERACTIVE MODEL

INTRANS alone is a set of relatively independent routines. To activate INTRANS requires that all these routines be tied together with specific model routines into one system. Figure 2 shows the elements needed for making an interactive model that uses INTRANS.

The major added element is the model's control program. Usually quite short, the program's main function is to call the interpreter and the required routines and retrieve and store the data based on instructions received from the interpreter.

Each model has its own set of command words. They should be entered into the required interpreter arrays in advance, using a special program. Each model usually has its own computing routines.

CURRENT STATUS AND PLANS FOR FURTHER DEVELOPMENT

At the present, the programming of INTRANS and the model BROWSE for data analysis has been completed. Manuals for interactive users and application programmers have been written (8). An extensive data set on the Chicago area has been assembled and used for experiments in interactive analysis. Thorough testing of BROWSE has been completed. A number of relatively simple additional models are being developed. One is a model for study of the behavior of the gravity and opportunity distribution models. The second is a model for estimating the spatial characteristics of the effect of pollution emission from the area's expressway systems.

Figure 1. INTRANS computer hardware.

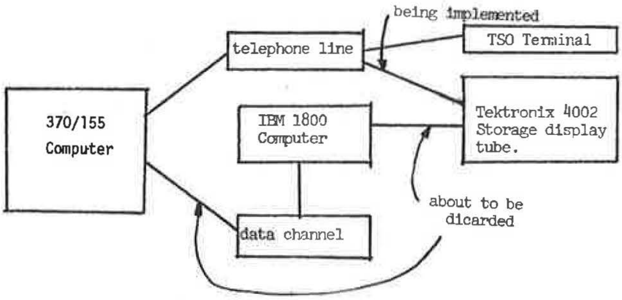


Figure 2. Structure of interactive model using INTRANS.

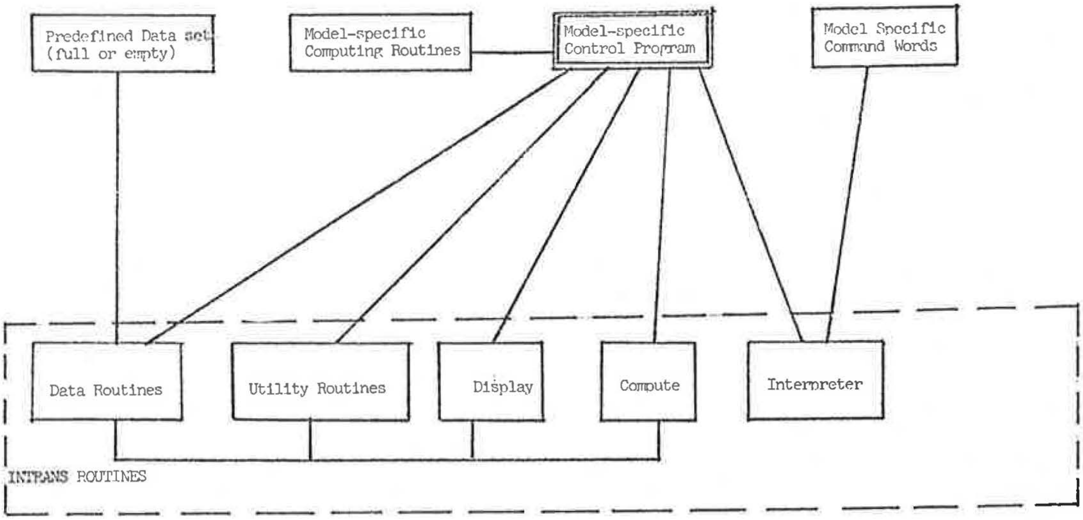
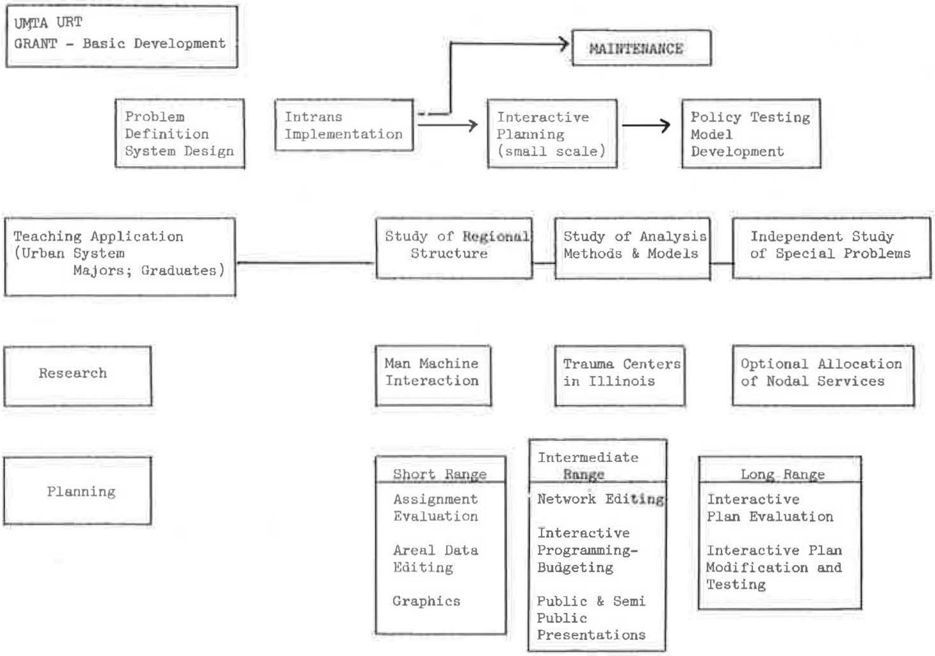


Figure 3. Tracks and major work items in INTRANS development.



Further development of INTRANS will be made in five parallel paths, as shown in Figure 3. This includes the development of INTRANS as a teaching tool, a research tool, and a planning tool. The two other paths are the maintenance and improvement of the existing system and the development of a general, large-scale policy-testing model (POTEM).

A Teaching Tool

At present, INTRANS may be used in teaching in a number of ways. First, students of urban systems may study structures of regions and relationships between intensities of various variables. Second, INTRANS may be useful in the study of graphic reporting techniques. Third, it is possible to use INTRANS as a laboratory for comparative analysis of the behavior of various models. With future availability of planning models, INTRANS may be used as a laboratory for interactive planning.

Limited experience during winter 1972 showed that effective use of INTRANS with the time constraints of a regularly scheduled course requires detailed development of laboratory manuals and problems. It seems that INTRANS can be used effectively mostly in advanced undergraduate and graduate courses because of the need for relatively wide background knowledge. Available time on the Tektronix also limits the amount of use of INTRANS for this purpose.

A Research Tool

INTRANS can provide substantial aid to research of problems with important spatial aspects. By using the available capabilities of the system, the user is relieved of much of the effort in data handling and analysis. This is additional to the ability to program specific problems for interactive data analysis.

Research projects that may use INTRANS are of a wide range of size and complexity. At one extreme, they may be student projects or independent study courses. At the other extreme, it may be possible to use INTRANS as an aid in large projects, particularly those that are data analysis oriented.

Developments in this area are expected to be initiated by researchers of specific problems rather than by the INTRANS development group. Thus, the extent and depth of use are unknown.

Currently, a number of projects are under way. First, there are three projects involving allocation of nodal services. One project is aimed at developing a multiple-root minimum tree-building program, which will be used in many optimal allocation problems. The second project deals with developing an interactive model for allocation of fire stations. The third project in this group uses INTRANS as an aid to study the allocation of trauma centers in Illinois.

A Planning Tool

Much effort has been spent to get planning agencies to use INTRANS as part of their activities. Only with experience in such applications will it be possible to develop the system to its full potential. In the immediate future, the most promising application seems to be browsing and editing of large data sets. Using the experience that will be gained in relatively simple applications will allow more sophisticated problems to be tried.

Currently, a study of the use of INTRANS by the Chicago Area Transportation Study is under way. It includes the experimental application of INTRANS for evaluation of a land use-activity data set and output of the transit assignment packages. Another project aimed to implement INTRANS as a "bank" for base information for the Illinois Department of Transportation.

ACKNOWLEDGMENTS

The research project described in this paper has been supported by a grant from the Urban Mass Transportation Administration, U.S. Department of Transportation, under the University Research and Training Program.

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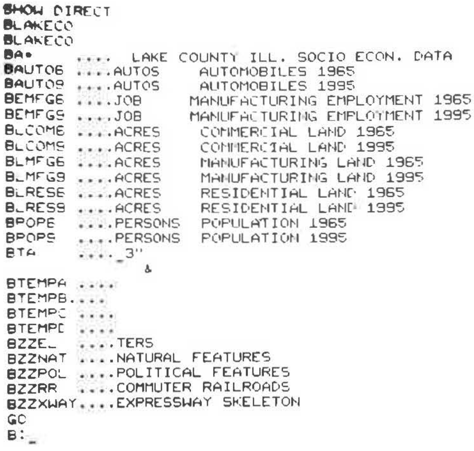
APPENDIX

TYPICAL INTRANS DISPLAYS

The following figures are reproductions of photographs of the screen, taken with a 35-mm camera on black-and-white film.

Figure 4. Directory of file BDLAKECO. Socioeconomic data on Lake County, Illinois, 1 grid = 1 mile square.



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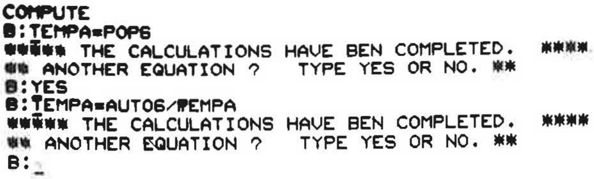
SHOW DIRECT
BLAKECO
BLAKECO
BA•       ....  LAKE COUNTY ILL. SOCIO ECON. DATA
BAUTO6   ....AUTOS      AUTOMOBILES 1965
BAUTO9   ....AUTOS      AUTOMOBILES 1995
BEMFG6   ....JOB      MANUFACTURING EMPLOYMENT 1965
BEMFG9   ....JOB      MANUFACTURING EMPLOYMENT 1995
BLCOM6   ....ACRES      COMMERCIAL LAND 1965
BLCOM9   ....ACRES      COMMERCIAL LAND 1995
BLMFG6   ....ACRES      MANUFACTURING LAND 1965
BLMFG9   ....ACRES      MANUFACTURING LAND 1995
BLRES6   ....ACRES      RESIDENTIAL LAND 1965
BLRES9   ....ACRES      RESIDENTIAL LAND 1995
BPOP6    ....PERSONS  POPULATION 1965
BPOP9    ....PERSONS  POPULATION 1995
BTA      ...._3"
             &
BTEMPA ....
BTEMPB....
BTEMPC ....
BTEMPD ....
BZZE_  ....TERS
BZZNAT ....NATURAL FEATURES
BZZPOL ....POLITICAL FEATURES
BZZRR  ....COMMUTER RAILROADS
BZZXWAY....EXPRESSWAY SKELETON
GC
B:_
```

Figure 5. Calculation on TEMPA-automobile ownership rate (core size for this version prevents storing more than two variables in core at once).



```
COMPUTE
B:TEMPA=POP6
***** THE CALCULATIONS HAVE BEN COMPLETED.  ****
** ANOTHER EQUATION ?   TYPE YES OR NO. **
B:YES
B:TEMPA=AUTO6/TEMPA
***** THE CALCULATIONS HAVE BEN COMPLETED.  ****
** ANOTHER EQUATION ?   TYPE YES OR NO. **
B:_
```

Figure 6. Displaying TEMPA as a function of its array location. Two extreme values indicate likely errors.

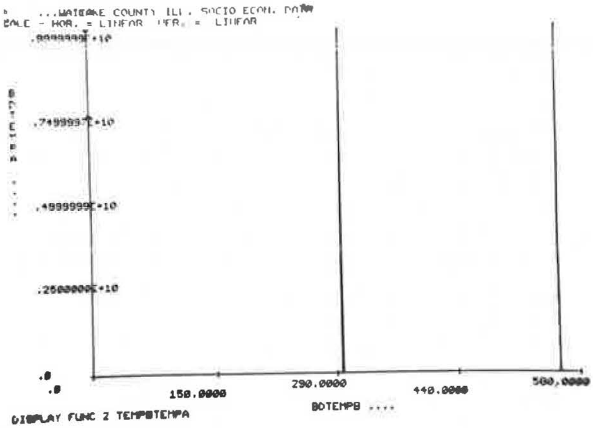
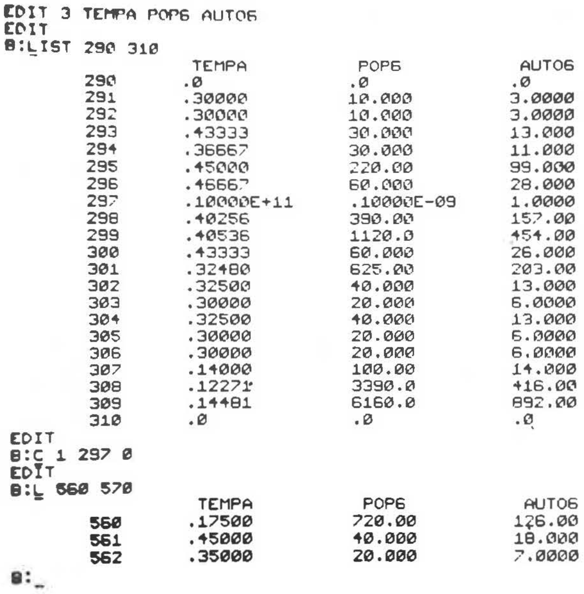


Figure 7. Editing the variables, to find and correct error in element 297 (making it 0).



```
EDIT 3 TEMPA POP6 AUTO6
EDIT
B:LIST 290 310
              TEMPA              POP6           AUTO6
     290     .0                 .0             .0
     291     .30000             10.000         3.0000
     292     .30000             10.000         3.0000
     293     .43333             30.000         13.000
     294     .36667             30.000         11.000
     295     .45000             220.00         99.000
     296     .46667             60.000         28.000
     297     .10000E+11         .10000E-09     1.0000
     298     .40256             390.00         157.00
     299     .40536             1120.0         454.00
     300     .43333             60.000         26.000
     301     .32480             625.00         203.00
     302     .32500             40.000         13.000
     303     .30000             20.000         6.0000
     304     .32500             40.000         13.000
     305     .30000             20.000         6.0000
     306     .30000             20.000         6.0000
     307     .14000             100.00         14.000
     308     .12271             3390.0         416.00
     309     .14481             6160.0         892.00
     310     .0                 .0             .0
EDIT
B:C 1 297 0
EDIT
B:L 560 570
              TEMPA              POP6           AUTO6
     560     .17500             720.00         126.00
     561     .45000             40.000         18.000
     562     .35000             20.000         7.0000
B:_
```

Figure 8. Map showing automobile ownership distribution in the region (overlayed with a grid in order to specify windowing).

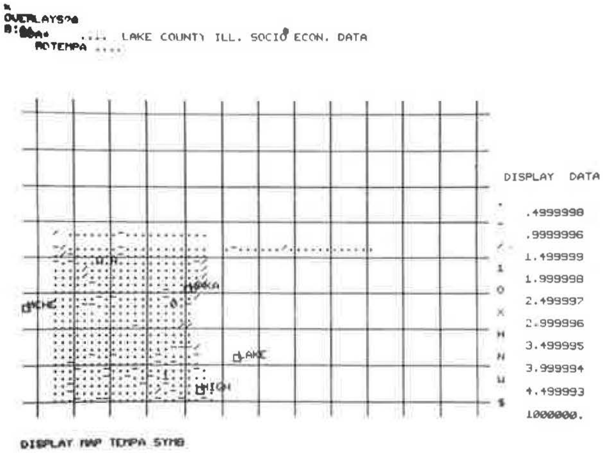
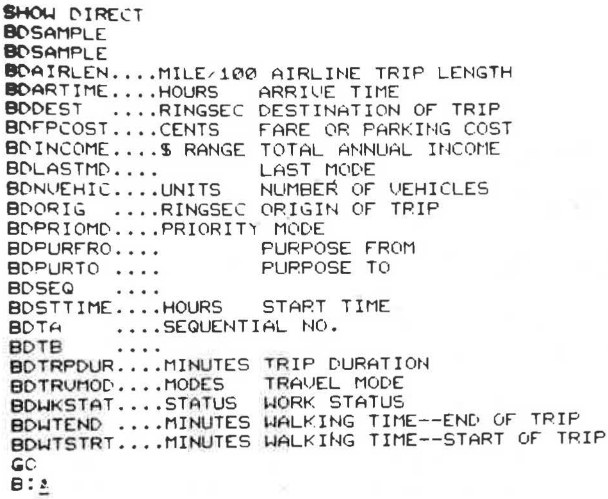
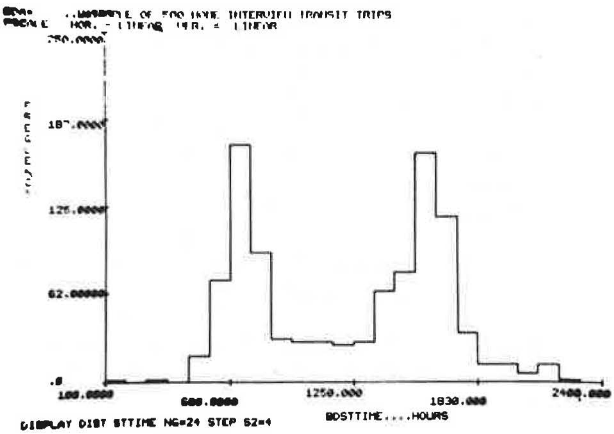


Figure 9. Directory of file BDSAMPLE (spatial data from a home interview, including a sample of 500 transit trips).



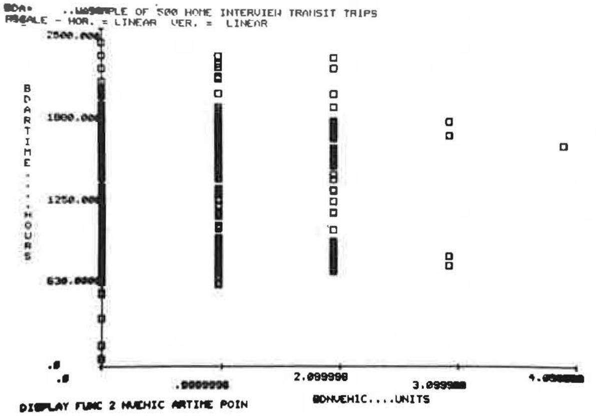
```
SHOW DIRECT
BDSAMPLE
BDSAMPLE
BDAIRLEN....MILE/100 AIRLINE TRIP LENGTH
BDARTIME....HOURS    ARRIVE TIME
BDDEST  ....RINGSEC  DESTINATION OF TRIP
BDFPCOST....CENTS    FARE OR PARKING COST
BDINCOME....$ RANGE  TOTAL ANNUAL INCOME
BDLASTMD....         LAST MODE
BDNVEHIC....UNITS    NUMBER OF VEHICLES
BDORIG  ....RINGSEC  ORIGIN OF TRIP
BDPRIOMD....PRIORITY MODE
BDPURFRO....         PURPOSE FROM
BDPURTO ....         PURPOSE TO
BDSEQ   ....
BDSTTIME....HOURS    START TIME
BDTA    ....SEQUENTIAL NO.
BDTB    ....
BDTRPDUR....MINUTES  TRIP DURATION
BDTRVMOD....MODES    TRAVEL MODE
BDWKSTAT....STATUS   WORK STATUS
BDWTEND ....MINUTES  WALKING TIME--END OF TRIP
BDWTSTRT....MINUTES  WALKING TIME--START OF TRIP
GO
B:
```

Figure 10. Relative frequency distribution of trip starting time.



```
DISPLAY DIST STTIME NG=24 STEP S2=4
```

Figure 11. Arrival time distribution as a function of automobile ownership showing increased concentration of trips during rush hours with increased automobile ownership.



```
DISPLAY FUNC 2 NVEHIC ARTIME POIN
```