The Dataplotter—A Tool for Transportation Planning

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THE ADVENT of computers has allowed, if not encouraged, the gathering and processing of data at ever finer levels of detail. However, the day when computer use reaches the ultimate in sophistication (that is, when after thorough digestion of much information, it will print a one-word message, "yes" or "no") has not yet arrived. Humans must still evaluate the computer's work and make judgments on its meaning. A major problem yet to be conquered is that of visual presentation of computer and even electronic accounting machine data summaries.

Credit for the initial recognition and at least a partial solution to this problem should be given to some unnamed sales manager. Long ago he gave up fumbling with cross-indexed lists and started sticking pins on maps. Later sales managers embellished this with colored pins and finally with flags. Now, when he wants to know who the salesman is in Des Moines, the sales manager looks at the name printed on the flag at Des Moines. How are sales doing there? The gold head on the pin tells him they're doing great—time to cut down on the territory and put in another salesman.

The advantages to such a system are obvious. How to apply these and other principles to the problems of transportation data reduction are not so obvious, but possibly much more useful. One available tool that can contribute to the solution of this problem is the dataplotter or the X-Y plotter. This machine can help and, in fact, is helping.

DETAILS OF DATAPLOTTER

The dataplotter (Fig. 1) is basically a machine for drafting straight-line segments between pairs of coordinates, or plotting points at single sets of coordinates X and Y. The machine also posts values of up to four digits at points located by coordinates.

Input to the machine being used by the Penn-Jersey Transportation Study (and manufactured by Electronics Associates, Inc., Long Branch, N. J.) is via punched cards; however, tape input machines are available at higher cost. Points for either the line-drawing or symbol-plotting mode are located by eight decimal digit numbers interpreted by the plotter as coordinates (four digits X and four digits Y). The machine recognizes negative values and, therefore, the maximum range is 20,000 counts (plus or minus 9,999) for either X or Y.

The machine traces lines, or plots symbols, on a 30- by 30-in. sheet of paper at a rate of approximately 20 line-segments per minute to approximately 50 symbols or points per minute.

Scale variations range from a maximum of about 7 counts per inch (on the plotting surface) to over 5,000 counts per inch. Changes of scale are made by means of potentiometer adjustment on the console, and both the X and Y directions are independently variable. Another feature of the machine is that of off-board parallax. This feature allows offsetting of the coordinate system center (zero point) so that all parts of quadrants can be traced on the full 30- by 30-in. plotting surface. Parallax adjustments are made similarly to those of scale factor and are done independently for X and Y.

In operation, the machine must be set before a run for either the line-drawing or the symbol-plotting mode. For line tracing, a pen-and-ink cartridge is manually fitted to the servo-arm. Various cartridges are maintained with different colored inks.
For symbol plotting, a symbol wheel is manually attached to the servo-arm. The symbol wheel has twelve characters, each automatically selectable by appropriate card coding. The twelve symbols are -, ., 0, 1, 2, 3, 4, 5, 6, 7, 8, 9. The symbols may be plotted singly or in groups up to four by locating only the first symbol with a set of coordinates. Thus it is possible to indicate on the plotting surface a value of 1, 10, 100, or 1,000 by locating only the first digit (one) by coordinates.

Input of data to the machine is by punched card which can be read serially or in parallel, depending on the type of card reader employed. For serial reading, the 024 keypunch machine is used. This machine reads the card column by column starting at column 1 and ending at column 80 and will selectively transmit some or all of the columns read to the plotter as operating codes, symbols, or coordinates, depending on the program card installed on the drum. For parallel reading, the 514 is used, and, depending on panel wiring, will transmit one field (one point or line terminal point) of information per card to the plotter.

Accuracy of the plotter is indicated by the manufacturer at 0.05 percent at full scale, plus or minus one bit of information for point plotting and 0.1 percent straight-line interpolation for lines up to 4 in. in length. The plotter will trace lines up to 15 in. in length at only slightly reduced accuracy, but it would be well to stay within the limit of approximately 15 in. where possible.

**Application to Transportation Analysis**

Because much of the data collected by the Penn-Jersey Study has been coded to grid coordinates, it has been possible to use the plotter for direct visual presentation of keypunched data. These applications have included use in contingency-checking data, dot map presentation, scattergrams, numerical presentation by symbol plotting, and drafting and presenting information about highway and transit networks.
Contingency Checks

The basic areal unit used by the study in the $\frac{1}{4}$-sq mi grid identified by three digits X and Y. Data coded to these units were then summarized to larger units such as traffic zones and districts or minor civil divisions. The plotter could then check the summarization of these units, and it was possible to determine miscodes or missing grids. Radical differences between adjacent grids are readily apparent on a visual basis.

Dot Map Presentation

The generation of vast amounts of socio-economic and trip data by large-scale transportation studies has defied rapid visual interpretation at a detailed level. Manual mapping techniques are limited to presenting highly summarized data. It has been found convenient to present this data at the grid level using the dataplotter. By stratifying the data summarized to grids into six groups, an effective color dot map can present information about population density, car ownership, trip density, etc. This can be increased in detail to include 10 or 100 strata or to the numeric value itself by changing to the symbol plotting mode or changing map scale. Examples of dot map presentations are shown in Figures 2 and 3.

A color dot map for the entire 1,200-sq mi study area can be completed in approximately two hours.

Scattergrams

An excellent application is the presentation of relationships between sets of data.

Figure 2. Character of land use outside cordon line by $\frac{1}{4}$-sq mi grid.
The plotter can produce scattergrams effectively and accurately using the point-plotting mode and data contained in two fields in a card. Scales can be varied to suit the data being related. The symbol plot can be used in conjunction so that individual points can be identified as well.

**Line Plotting and Applications to Traffic Assignment**

The line-plotting capabilities are put to use in checking and presenting data about highway and transit networks.

It has also been possible to check for contingencies in networks coded for computer traffic assignment. The plotter output has been used to check the keypunched network computer input data visually for missing links or incorrect identification of nodes and speeds.

Output of computer traffic assignments has also been presented. By stratifying the assigned volumes into ranges, an effective color map (similar to a flow map but the color changes representing volume ranges rather than width) of the assigned volumes can be drawn at the rate of 20 links per minute. Individual link volumes can be plotted at the midpoint of the links by subdividing the area and using the symbol printer at larger map scales. Other data about the links in a network (such as volume-capacity ratios) can be presented in this form. The minimum path "trees" traced by the computer for trip loading have also been plotted for analysis. Figure 4 shows a section of a highway network with line segments and coded speed values drawn and posted by the dataplotter.
Other Applications

The presentation of desired lines of travel information has long plagued transportation planning agencies. The problem has always been to present the available data with clarity without sacrificing detail.

The first attempts were to connect each zonal pair with a straight line, varying the width of the line to represent the amount of travel between the zones. This consumed many man-hours of drafting time, and resulted in a picture approximating a blob of ink. The next attempt accumulated desire lines into broad bands termed "major desire lines." This cleaned up the map somewhat, but lost a great deal of detail and tended to show only major movements. Results also varied with the size and shape of the zones or districts considered.

The Detroit Area Transportation Study (DATS) used a contour line desire presentation, developed by the California Division of Highways. This method overcame some difficulties and introduced others. It was necessary to portray separate maps for desires in eight principal directions. Interpretation became somewhat difficult. The Chicago Area Transportation Study (CATS) then developed the cartagraphatron to present existing travel patterns in Chicago (1). Hand drafting was eliminated, and grid-to-grid movements could be presented. Trips could be rapidly stratified and studied by length, purpose, or other classification. This method has also been used by the Pittsburgh Area Transportation Study (PATS).

Figure 5 shows a technique recently developed at Penn-Jersey for the presentation of desire lines of travel via the dataplotter. The darker lines in the picture indicate higher travel demands and the lighter lines indicate lesser demand values. In practice, these lines are in color, ranging from light yellow through black, thus yielding higher resolution.
Figure 5. Desire line density map of mass transit trips.

Figure 6. Abstract grid framework for desire line loading, circles indicate grid centers.

Figure 7. Trace patterns for exact east-west, north-south or 45° diagonal desires.
The preparation of such a map involves the loading of a network by computer. The program for this purpose operates in a manner similar in some respects to assignment programs that load abstract highway networks. Instead of highway sections, however, an abstract grid network system is used composed of some 6,400 grid centers (nodes) connected to each other via straight lines (links) as shown in Figure 6. Any movement is loaded from origin to destination only via those links comprising the shortest route, and the movement value is accumulated in each of the links involved in the route. Figure 7 shows the loading of simple, straight line movements. A movement from, say, grid G to grid C would have its value accumulated on the link from G to E and from E to C. Figure 8 shows the more complex case where the desired line of travel does not exactly match any of the inherent network directions. The routing and loading of such a movement is accomplished as shown by the heavy lines. The rule here illustrated is simply that the routing of the movement follows, as closely as possible within the limitations of the grid network a straight line from the origin grid to the destination grid. The special case where two equally satisfactory routes are available (see Fig. 9) is handled by means of alternate loading of both of the available routes.

The product of the program described is a punched-card deck containing one card for each loaded link in the loaded system. These cards are then stratified according to the grid interchange volumes indicated and each group is run on the dataplotter with a different colored pen, the lower volumes with lighter colors and the higher volumes with darker colors. The result is a map similar to that shown. It is also possible to print the actual link volumes at the grid interchange points if desired.

Some effort has been devoted toward making the computer program, which was written for the IBM 7090, as flexible as possible. The capacity of the program is a maximum of an 80- by 80-unit grid center matrix which can be made as fine or as coarse as is consistent with the maximum dimensions by the use of constants for enlargement or reduction of grid values before loading. The program was designed to accept detailed or summarized movement records for loading, and provision has been made for selective loading of records from an intact magnetic tape file.

SUMMARY

The intent of this paper was to introduce the applications of the dataplotter to transportation analysis. Although some of the applications mentioned have been illustrated, the data summarized to date by the study does not provide the best illustrations or indicate all of the techniques or refinements to be explored. For these reasons, this report should be regarded as preliminary. More data, and more experience, should provide material for a more detailed report at a later date.
REFERENCE