INTRODUCTION

Transportation planning involves analyses and forecasts of travel demands, and recommendations regarding appropriate transportation services and facilities to meet these anticipated travel demands. Because of the flexibility and utility of Statistical Analysis System (SAS) procedures, many of these procedures may be used to present comparisons, rankings, plots, charts, and other statistical analyses.

Graphic presentations can be very beneficial to both transportation planners and decision-makers. A transportation planner can use SAS/GRAPH procedures to compile and analyze data, perform specific tasks, and summarize results with descriptive graphic displays. Obviously, transportation planners must also make decisions. Within the context of this discussion, however, decision-makers are considered to be citizens, public officials, corporate managers, and other individuals who must make recommendations on the basis of the analytical results presented by transportation planners. Thus, transportation planners are considered researchers or analysts, while decision-makers are the implementors of changes in the transportation system.

The transportation planning process generally followed by state and local planners is comprised of four types of analyses. The four analyses are:

1. trip generation,
2. trip distribution,
3. modal choice, and
4. trip assignment.

Presenting a detailed review of each of these analyses is not the major intention of this study. However, a brief discussion of each type of analysis is required so that the reader understands the requirements and approaches used in each phase of the process. With this basic knowledge, the reasons for applying specific techniques in SAS will be more easily understood. Hopefully, these suggested uses of SAS will be viewed in a much broader context. The same SAS techniques can certainly be used in similar ways to present concise information on a variety of other important topics in addition to transportation.

Thus, the next four sections of this study present facts about the information required in each of the four phases of the transportation planning process. Designing and selecting charts which will focus rather than dispel attention is then discussed. A transportation case study is then highlighted to illustrate specific examples of how SAS/GRAPH procedures were successfully used to define and to solve transportation problems for a large employment complex. The presentation of several conclusions and recommendations completes the study.

TRIP GENERATION

Trip generation is the analytical process by which the planner projects the number of trips which will originate or terminate within each traffic zone of the study area. These origins and destinations are known as trip ends. Prior to the determination of these trip ends, the study area is broken into smaller traffic zones for which specific socio-economic and land use data are available.

Trip models are then developed using available socio-economic and land use data to forecast the number of trips ends, or productions and attractions, which will originate and terminate within each traffic zone. Past experience has shown that more reliable models can be derived if separate estimates are made for different trip purposes. Thus, separate production and attraction models may be developed for different trip purposes such as work, personal business, school, shopping, and other types of trips.

Trip generation models attempt to establish meaningful relationships between land use, socio-economic data and trip making activity so that changes in land use and socio-economic data can be used to forecast related changes in transportation demand. Cross classification analysis and regression are two frequently used methods for developing trip generation models.

Cross classification analysis is a method of indicating the value of the response variable (e.g., person trips), at various levels of one or more independent prediction variables. Cross classification analysis can be used to plot a family of curves showing changes in one independent variable while others remain at constant levels. These plots enable planners to study the sensitivity of changes in various independent variables. Cross classification tables can be produced with the FREQ procedure. The interpolation option of the GPLOT procedure can be used to plot a family of curves.

Multiple regression techniques are probably the most widespread method of trip generation analysis. A typical regression equation might be as follows:
After completing the trip generation phase of which govern interchanges in the base year. The modeling process, the transportation plan—trip productions and attractions for each traffic zone. The pairing or linking of various trip ends is not yet known. In other words, answers to questions about the number of trips between zones and by what routes are not available. Trip distribution models solve the first of these two questions by calculating "trip interchanges" according to criteria which govern interchanges in the base year.

The gravity model, so named because of its similarity of Newton's theory of gravity, is the most frequently used technique for distributing trips or creating trip interchanges between traffic zones. This model involves detailed mathematical calculations and is calibrated against existing origin-destination data. Thus, specific calculations performed by the gravity model will not be presented here.

**TRIP DISTRIBUTION**

After completing the trip generation phase of the modeling process, the transportation planner has knowledge about trip ends only, or trip productions and attractions for each traffic zone. The pairing or linking of various trip ends is not yet known. In other words, answers to questions about the number of trips between zones and by what routes are not available. Trip distribution models solve the first of these two questions by calculating "trip interchanges" according to criteria which govern interchanges in the base year.

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**MODAL CHOICE**

The purpose of this phase of the transportation planning process is to split person trips into auto vehicle trips and transit person trips. This phase is sometimes omitted if transit trips are not considered. Factors often used in modal choice models to predict modal choice are:

1. types of trips,
2. characteristics of the trip maker, and
3. relative levels of service per mode.

There is no single modal choice model which is predominantly used. Modal split analyses have been conducted by diversion curves, cross classification matrices, regression analysis and other techniques with varying degrees of success.

**TRIP ASSIGNMENT**

The final process in the transportation planning process is the assignment of zonal trip interchanges to the individual transportation facilities. Thus, trip assignment places traffic volumes on each portion of the transportation system. The planner can check base year assignments against observed traffic volumes to evaluate the accuracy of the model. The planner then uses the model to forecast future trip interchanges on proposed facilities, and to evaluate the capacity of the transportation facilities to accommodate anticipated travel demand. Diversion curves, iterative capacity restraint algorithms, and equilibrium algorithms are several of the more frequently used techniques.

**CHART DESIGN AND SELECTION**

Many people have had the experience of glancing at a chart or a set of charts in a magazine or a textbook and making a quick, often unconscious, decision concerning whether to take the time to understand the construction of the chart and the information portrayed. The presence of a chart between pages of text intrudes into one's relatively fast sentence scanning pace in much the same way that reading a mathematical formula or computer code invades one's sentence reading mind set. This drastic pace slowing can frustrate to the point that one simply skips the chart or the formula, hoping to get the gist from the text information with no irritating loss of momentum. On the other hand most everyone can also relate to the experience of turning through a magazine and coming to a multi-page article on the state of the economy that includes one or two bold, colorful charts nestled in the right column of the first page. At this point digesting the chart as an alternative to reading cautious and boring or overstated and sensational comments by economic pundits becomes very attractive. Choosing to digest the charts and read the text later often gives a satisfying sense of drawing personal, independent conclusions. After all, one is looking at the hard data.

Graphs have immense power to attract or repel attention, depending largely on design and presentation. This may have less impact on the transportation planner, who must translate graphical data representation into reports, plans, and recommendations. Well designed graphical output will certainly enhance the transportation planners quality of work life, but they will probably settle for graphs that look like they came out of an abstruse college textbook. Perhaps they will not even realize that unlike the ones in the textbook, these graphs are cluttered through carelessness rather than because they represent some sophisticated relationship that cannot be portrayed in a simpler way. The vocal involvement of lay people and the necessity of dealing with densely clustered spatial relations such
as city geography make this a particularly important consideration in transportation planning. In fact, one of the authors shares the experience of many people who have difficulty reading a city street map (not Dr. Stammer, fortunately). Yet as stated before the transportation planner often wants to present graphs to citizens, public officials, corporate managers, and other decision-makers. If the planner wishes to facilitate understanding, feedback, and commitment rather than to impress by confusion, the graphics presented must be well designed and well chosen.

The following discussion of graphics choice and design will focus on that subset of graphing which is charting. Facilities available in SAS/GRAPH and in the GCHART procedure in particular will be the springboard for this discussion, though several of these considerations have implications for charting and graphing in general.

A well designed chart gives significant attention to who is going to view the chart. A situation common in transportation planning is a mandate to produce charts for several involved parties with widely varying chart reading ability and patience. For example, charts showing morning commuters trips by corridor and route might aid and interest both transportation planners in analyses and the transportation decision-makers in plan implementation. In transportation terminology, a corridor is a sector of the total study area that contains several alternative transportation facilities (e.g., north corridor, southeast corridor). A route is a path along which transportation by various modes is accomplished (e.g., major arterial route, rapid rail route). A pie chart and a vertical bar chart showing frequencies of trips down various corridors could be produced for the decision-maker. A horizontal bar chart of the same breakdown might be of more interest to the planner because of the listing of percentages, cumulative percentages, and cumulative frequencies for each bar. The planner could further make use of a horizontal bar chart showing frequencies in trips along various routes. More details on the routes within the corridors might be presented to the planner in a set of horizontal bar charts using the same HBAR statement as in the above with corridor as a by-variable and a preceding sort by corridor. Most of the process could be summarized on two pages in a horizontal bar chart and a block chart of route using corridor as a group variable. Planners might once again make better use of the horizontal bar chart.

Decision-makers, who might never have seen a block chart before, could peruse the lined pathways through the buildings of various size suggestive of their transportation empire.

Two non-exclusive strategies can be employed in selecting charts for presentation. One may decide which charts to produce or one may select from a group of produced charts. When one type of chart is designed with SAS/GRAPH, other types of charts with the same data breakdown are usually extremely easy to produce. Thus, one strategy is to produce a pie chart, a horizontal bar chart, and a vertical bar chart for each data breakdown desired. Block charts are not included in this list because they are generally appropriate only if a group variable is used and often require significantly greater VPOS and HPOS specifications. By responding to the actual charts the chart producer can select some charts for presentation as they are, delete some charts from consideration, and select some charts for modification. From this perspective the suggestions in this section can be viewed as descriptive criteria for post production selection of charts in addition to guidelines for chart production.

Attracting and focusing the attention of the viewer as a fundamental principle of chart design should be remembered when presenting charts to a particular group of viewers. The sparsity or density of visual information presented in a chart is another important dynamic of chart design. The interrelationship between viewer attention and information density considerations is exemplified by the process of selecting an effective combination of pattern statements and a subgroup variable. Since specifying a subgroup variable identical to the charted variable is an effective and frequently used method to simply enable pattern statements for a particular chart, a subgroup variable different from the charted variable will be referred to as a nonidentity subgroup variable. A chart with a nonidentity subgroup variable offers more information on a bar area of equal magnitude and a page area of similar magnitude to the same chart without a subgroup variable. If the fundamental purpose of the chart is to get the viewer looking at the chart rather than skipping it entirely, then the combination of widely varying pattern statements with a nonidentity subgroup variable can serve as a strong visual attractor. The slanted shading, cross hatching, emptiness, and fullness of different bar segments is visually alluring. However, the different apparent motions of some of the bar segments can make both extended attention to bar segment magnitude and focus on the more global data relationships represented in the chart a difficult task. Thus, charts with widely varying pattern statements and a nonidentity subgroup variable should be used sparingly if at all. The specification of the charted variable also as a subgroup variable together with these same pattern statements will produce a chart with similar visual allure but less dissipation of attention. The decrease in dissipation seems to result from the fact that in the latter case the different patterns are in different bars rather than right next to each other in the same bar. Color charts with multi-colored, solid bar segments and black and white charts with empty bar segments are minimally dissipating pattern specifications if bar segmentation is absolutely necessary.
Maximum focus on more global data relationships is achieved by using no bar segmentation at all. The use of a group variable is another way of attacking the problem of densely packed data subdivision. Appropriate group variable use will provide separate bars for each of the data subdivisions and the resulting chart will be much easier to study. Because the chart axis is longer with a group variable, a horizontal bar chart is usually a better choice than a vertical bar chart unless one wants to take the trouble to form a compensating GOPTIONS statement. Remember that two variables are being charted when a group variable is used. The variable whose values are to appear nearest the chart axis is coded right after HBAR or VBAR. The variable whose values are to appear farthest from the axis is coded after GROUP=. The following example translates a chart specifying a subject to this consideration:

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HBAR CORRIDOR/SUBGROUP = ROUTE;
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becomes

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HBAR ROUTE/GROUP = CORRIDOR SUBGROUP = ROUTE;
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An invitation to explore personally further issues in chart design and selection will conclude this section. An aesthetic sense and some sense of play should be allowed to exist in the creation of charts, or the process becomes in time substantially different from basic page formatting mainly in the sense that one has to worry about far more than line and column position of fixed reproduction characters. The ease of creating a larger set of charts than will be used ultimately has already been highlighted. Judicious and conservational use of this facility removes one barrier to informed playful experimentation. One of the few things produced by a computer, used effectively by a technically esoteric person, and yet comprehended by a young child is a pie chart. A working perspective with an eye toward this kind of concern could remove other barriers.

Preceding discussions have presented information about the four phases in the transportation planning process and how SAS procedures may be used to assist both planners and decision-makers. The following case study illustrates more specific applications of SAS procedures which were used during a major transportation study for a large employment complex.

**Background Information**

This case study describes how SAS was a valuable planning and decision-making tool in a major transportation study for the Union Carbide Corporation - Nuclear Division (UCC-ND) in Oak Ridge, Tennessee. The study accomplished the following objectives:

1. inventoried existing transit services within and between three UCC-ND operated plants.
2. monitored the travel patterns of approximately 1,100 company vehicles for one month, and
3. recommended transit improvements and fleet management strategies to transport employees more effectively and economically and to conserve energy.

SAS procedures such as FREQ, MEANS, GCHART and others were used to accomplish these objectives by presenting both simple statistical summaries and detailed graphics. Results from SAS/GRAPH were particularly informative to management since slides from SAS/GRAPH simplified data analyses and presented transportation facts in a very informative format.

Several transportation challenges exist at the UCC-ND operated facilities in Oak Ridge. First, using over 1,100 vehicle in an efficient manner to transport personnel and materials is no small task. Secondly, operating intraplant and interplant transit services to satisfy diverse travel demands, various security requirements, and different plant layouts is difficult. This is further illustrated by the fact that the UCC-ND transit system, in terms of total yearly ridership, is the sixth largest operation in the State of Tennessee.

**Analyses of Data**

Several programs written in SAS were used to compile and present both transit and vehicle trip data after the data were keypunched. SAS/GRAPH was especially useful since emphasis on visual presentations of information were stressed throughout the entire analysis process. The graphic displays were useful to researchers in developing recommendations and informative for UCC-ND officials responsible for major transportation decisions.

Pie charts were used to illustrate transit riderships per service type. Horizontal bar charts were also used to illustrate ridership per service type, but the analysis was taken one step further since the individual services could be ranked in descending sequence. This analysis showed which services were most heavily utilized.

Analyses of graphs revealed:

1. Current service demand peaks three times a day as opposed to the morning and afternoon peaks normally encountered by public mass transportation.
2. The midday or lunch peak is, in fact, the greatest and accounts for about one-third of the total daily ridership.

3. Riderships are slightly higher on days of inclement weather.

Management learned from these analyses that a disproportionate amount of resources were being devoted to interplant transit services. The resources are disproportionate in terms of current ridership levels since 31.2% of total transit costs and 26.7% of all transit vehicles transport only 15.2% of the total transit ridership.

Major origins and destinations of vehicle trips were obtained using the FREQ procedure. A manually prepared map locating major origins and destinations was then prepared. The analysis was taken one step further by determining major origin-destination pairs through the creation of a ranked pointer nexus. Desire lines connecting origins and destinations were plotted and proved to be a helpful visual aid in understanding travel patterns. These maps were used for studying existing vehicle travel and for designing transit systems to serve these needs better. Other analyses studied trip lengths, selected trip purposes, trips by day of the week, and various combinations of these categories. Horizontal bar charts showing average trip length and average trips per vehicle by plant suggested certain inefficiencies and was important to management in assessing vehicle fleet adjustments.

Final graphical analyses showed vehicle trips by purpose for each plant.

Study Conclusions and Recommendations

Due largely to useful SAS output, important and useful conclusions were identified. The more salient conclusions were:

1. Present transit systems were not being used to desired levels.

2. Transit services devote a disproportionate amount of resources to interplant travel, while person trip travel demand for intraplant appeared to be much greater.

3. Transit service and route changes and reductions in the availability of company vehicles should result in increased transit ridership.

4. Current fleet vehicles are severely underutilized.

5. A disproportionate amount of vehicle trips are less than one mile (71.6%) and elimination or more efficient ways of traveling should be investigated.

6. Single occupant vehicles make 60.5% of all vehicle trips.

7. Vehicle fleet and transit system modifications are necessary.

Four major recommendations were presented to UCC-ND management. The four recommendations were:

1. Relocate existing transit resources to serve predominant intraplant person trips more efficiently. Less labor intensive carpooling arrangements for several existing interplant shuttles.

2. Reduce the current vehicle fleet by at least 133 vehicles (about a 10% reduction). Specific vehicles were identified and consideration of further reductions should be considered in one year.

3. Develop criteria for an ongoing vehicle utilization review process using existing vehicle maintenance records.

4. Review transportation planning, administration, and operations in each plant so that control and responsibility is centralized and definable.

SUMMARY

SAS procedures and programs have been proven to be very flexible and useful in answering questions about long range transportation planning, as well as for specific studies. Numerous comparisons, rankings, and other statistical analyses can be efficiently performed. Visual presentations of pertinent transportation data were by far the most useful to both planners and decision-makers. These graphic presentations allowed planners and decision-makers to analyze the data in much greater detail than would have been possible by other techniques. Procedures have advanced to the stage where slides and other materials are quickly obtained and can greatly assist management in assessing complex conditions.

Finally, it is important to recognize that the techniques for using SAS presented in this study can also be used in a variety of other situations. Transportation planning is only one of an endless list of subjects which can be studied. The same types of rankings, comparisons and graphic summaries can be used beneficially in countless other situations.

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