Techniques for Monitoring Automobile Occupancy: Research in the Seattle Area

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Research directed at developing and testing analysis techniques for evaluating changes in average automobile occupancy is reported. The goal was to develop low-cost techniques that would be sensitive to variables of season, time, and commuting distance and then to test several hypotheses that relate to variations in the parameters of automobile occupancy. A list of four study tasks was drawn up, and data on automobile occupancy were collected at a number of sites in the Seattle region over a 15-month period. Statistical techniques that specifically address the issue of automobile occupancy were developed. The data were synthesized by computer and analyzed statistically to determine whether patterns existed among sites or over time or distance. The results show no predictable patterns or trends in automobile occupancy by type of facility, traffic volume, level of transit service, distance to the Seattle central business district, month or season, day of week, or time of day. These results contradict initial hypotheses that patterns did exist that would make an abbreviated count program sufficient for measuring changes in automobile occupancy. Other variables that might relate to automobile occupancy are identified, and areas for further study are suggested. Guidelines are presented for other transportation engineers who may wish to conduct monitoring studies of automobile occupancy.

Federal, state, and regional transportation policy has recently been redirected from increasing capacity to accommodate travel growth to increasing vehicle occupancy to handle travel growth as well as reduce fuel consumption, manage congestion, and control air pollution. As policy is redirected, decision makers begin to look for some form of measurement that will tell them about the effects of the policy shift. Attempts to measure such a change have been uncertain at best.

Vehicle-occupancy counts have not been collected on a systematic basis so as to indicate the effect of commuting distance, seasonal variation, access incentives, or regional programs for carpool development. Such counts require expensive person hours of field observation in poor working conditions.

During the 1960s, when transportation planning was done on a regional, systemwide basis, a series of home-interview transportation surveys were taken in regions around the county, including Puget Sound. The purpose of this data gathering was to survey automobile occupancy for all trip purposes as an aid in calibrating transportation system models.

More recently, federal policy has emphasized short-range transportation system management (TSM) techniques to derive greater efficiency from the existing system. There has increasingly been a call to look at the existing system, find the congested spots, and consider priority treatment for high-occupancy vehicles (HOVs) as a way to ease congestion and induce greater efficiency. It is recognized that, if ride sharing is to be significantly increased, real incentives such as time savings are required. Unfortunately, a good data base for automobile occupancy—one that is "corridor specific" to indicate what currently exists and help estimate what would happen if existing conditions were modified—is not available.

For instance, in the Seattle area, two modifications were made in the mid-1970s on the Evergreen Point Bridge that links Seattle with suburbs east of Lake Washington. During the energy crisis, the regular 35-cent automobile toll was reduced to 10 cents for vehicles with three or more occupants. In 1975, an exclusive HOV lane was added along the westbound approach to the bridge; that lane provides HOVs with as much as a 6-min advantage to the head of the queue in the morning peak period.

How effective have these techniques been? When planners tried to answer that question, they discovered a dearth of reliable automobile-occupancy data for the period before the toll reduction and institution of the HOV lane. In addition, occupancy values after the differential toll was instituted fluctuated widely depending on the season, the day of the week, and the type of crew that collected the data. For a number of months after the change in the toll, planners were unsure of the significance of the findings since no statistical guidelines were available. With this gap in knowledge in mind, the Seattle-King County Commuter Pool Program, a regionally funded ride-sharing project, responded to a general Federal Highway Administration (FHWA) request for proposals on techniques for monitoring automobile occupancy.

The premise of the research was that sampling techniques existed that would enable an ongoing regional program to be implemented, at a relatively low cost, to monitor changes in vehicle occupancy that result from various transportation system strategies. The program would also meet the requirements for urban transportation data reporting suggested to the U.S. Department of Transportation (DOT) by the Transportation Research Board (1). The sampling techniques would be sensitive to the variables of season, time, and commuting distance and would test them against baseline occupancy data for the morning peak period. This would provide the basis for a low-cost monitoring program for use by regional TSM programs throughout the country and specifically in the Puget Sound region.

Why the morning peak? The researchers decided to use the morning peak period because most ride-sharing strategies are directed at the work trip, which is repetitive in nature and has the lowest vehicle occupancy of any trip purpose. It is also the time period in which the highest percentage of work trips are made in the shortest time span. The evening peak is longer and flatter and includes other trip purposes that would not be particularly sensitive to HOV incentives.

To achieve these objectives, vehicle-occupancy counts were taken over a 15-month period in the Seattle area to provide data for a number of individual analysis tasks. Briefly, these tasks were to determine the following:

1. Whether occupancy rates vary in a consistent, predictable manner, by month or season of the year, by day of the week, or by time of day;
2. Variations in occupancy rates as a function of

distance from the Seattle central business district (CBD) along major corridors;

3. Occupancy rates at stations along the CBD cordons for Seattle, Bellevue, and Renton; and

4. The degree of statistical variation in occupancy counts as a function of the technique of data collection and the rate of traffic flow (redundancy counts).

The data were synthesized through several computer programs and then analyzed statistically to determine whether significant differences existed among the various counts and what factors might explain any variations.

One interesting relation to keep in mind throughout this paper is that between the average automobile occupancy for a site and the percentage of persons in vehicles with three or more occupants. Plotting points for a number of sites on a set of axes according to their values on these two variables yields a visual indication of the type of ride sharing at each site (see Figure 1). Points located farthest from the regression line of all data points have high proportions of either (a) riders in two-occupant vehicles compared with riders in vehicles with three or more occupants or (b) vice versa. A graph such as this may be of particular value in assessing the effects of a carpool-incentive program. In the Seattle area, for instance, a carpool must be a vehicle with three or more occupants to qualify for reduced tolls and exclusive lanes. Thus, a new carpool incentive in a corridor would benefit only riders in vehicles with three or more occupants and not ride sharers in two-occupant vehicles. Monitoring the movement of the point for a site on this graph over time will reveal whether, for an increase in carpools with three or more riders, these ride sharers are being drawn from single-occupant automobiles or vehicles that previously carried two riders.

These shifts cannot always be determined from average automobile occupancy alone. Since the ultimate goal of a carpool-incentive program is to increase the person-carrying capacity of a corridor, other measures in addition to average automobile occupancy may be of value, especially to persons unacquainted with occupancy studies. For instance, the change in degree of ride sharing at a site after the start of a carpool-incentive program could be described in several ways. One would be to state that average automobile occupancy rose from 1.242 to 1.269, but a more meaningful statement to the layperson might be that the percentage of people sharing a ride increased from 36.1 to 38.5 percent.

The various components of the Seattle area study are discussed in the following sections of this paper.

DATA COLLECTION PROCEDURES

First, it was necessary to determine at how many sites automobile occupancy should be surveyed and where these sites should be located to maximize their usefulness. Figure 2 shows the primary highways and employment centers in the Seattle region. For the task that involved corridor variations, counts were taken once only at every inbound on-ramp along I-5 North, I-5 South, WA-520, and I-90 and at selected northbound and southbound on-ramps along I-405. For the analysis of the CBD cordons, occupancy was surveyed at stations and ramps that encircle the Seattle, Bellevue, and Renton CBDs.

For the remaining tasks, which involved variations over time, a number of site-selection criteria were considered by the study team. These included the type of facility (expressways, expressway ramps, and arterials in both the central city and the suburbs), traffic volume (a variety within a reasonable range to reduce the effects of sample variation but to stay within staff and budget constraints), level of transit service (a range from no direct commuter transit service to 42 buses in the peak two hours as well as corridors that serve park-and-ride lots), land-use characteristics (a mix of densities at varying distances from the Seattle CBD), and general utility for future planning efforts. By using these general criteria, the study team drew up a list of potential sites and then selected 18 regional sites from this list (Figure 2).

To explore monthly and seasonal variations, a midweek (Tuesday, Wednesday, or Thursday) occupancy count was scheduled once each month at each of the 18 sites in the region over the 15-month survey period. For the analysis of day-of-week variation, 7 sites were selected from the pool of 18 sites; these were chosen to represent a variety of characteristics according to

Figure 1. Relation between average automobile occupancy and percentage of persons in vehicles with three or more occupants.

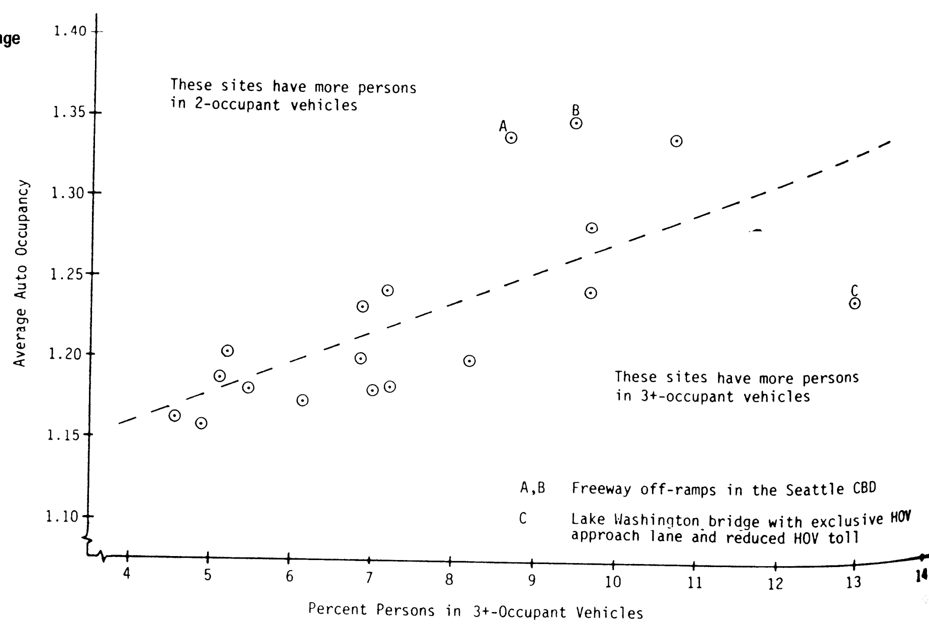
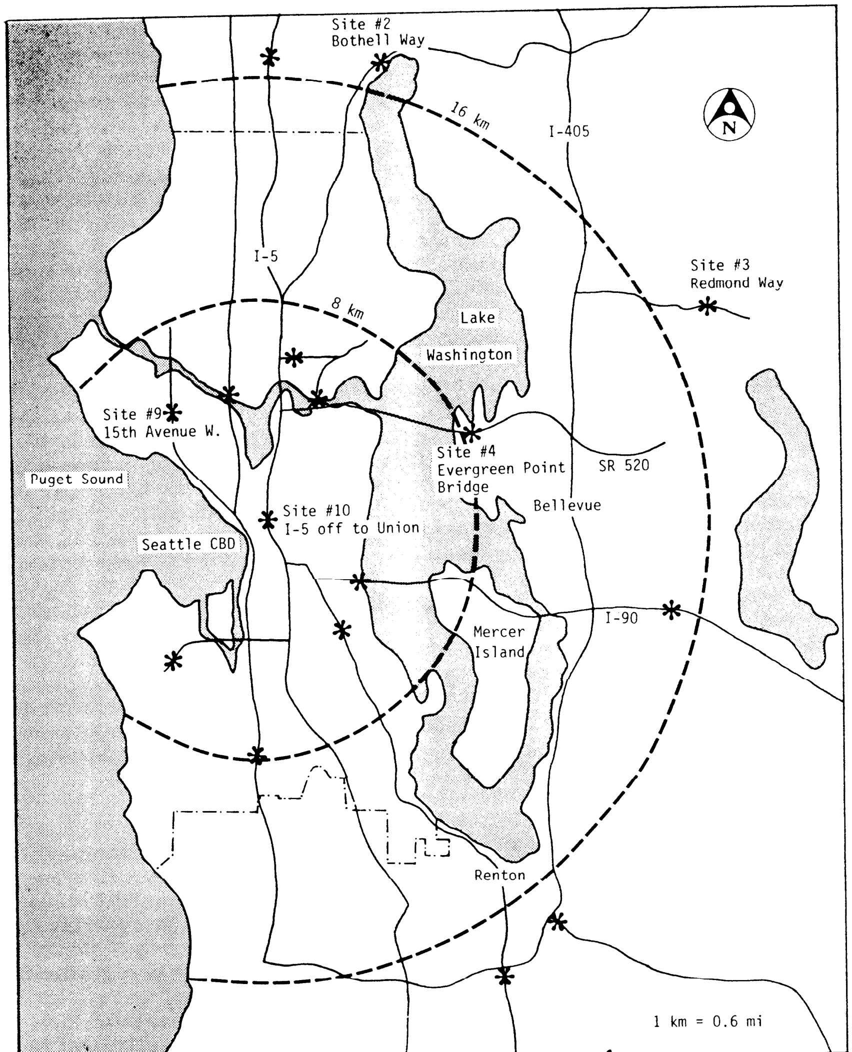


Figure 2. Seattle regional highways and survey sites.



Note: Only 16 stars are shown for the 18 sites because two of the stars identify two sites each (located adjacent to each other).

the criteria outlined above. Counts were conducted four times a year on five consecutive weekdays at these 7 sites. Three sites (suburban, urban, and CBD) were selected for the time-of-day analysis, and two 12-h occupancy surveys (autumn and spring) were conducted at these sites. (The process of site selection for the analysis of redundancy counts is described later in this paper.) For all tasks except the analysis of time-of-day variation, the morning peak period (6:30-8:30 a.m. or 6:45-8:45 a.m., whichever had the greater traffic volume at a site) was selected for occupancy counts.

Techniques for gathering the data were fairly straightforward. The members of a crew of traffic recorders were each assigned a particular count for a particular 2-h period and were each supplied with a five-register pushbutton counter and a sheet for recording the data. The five registers were to be used for counting vehicles with one occupant, those with two occupants, and so forth up to vehicles with five or more occupants. Motorcycles were included, but buses and commercial trucks were not. Pets and inflatable dolls were also excluded. Except for the 12-h time-of-day counts, during which both directions of traffic flow were surveyed, only the major direction of flow was counted.

At 15-min intervals, the counter would record the data on the data sheet; each 2-h count thus yielded eight 15-min-interval counts. These data were synthesized through a computer program that produced a summary printout of occupancy parameters for each interval and for the 2-h period. It was these 2-h summary values, broken down by one-occupant vehicles, two-occupant vehicles, and vehicles with three or more occupants that were subsequently analyzed statistically to explore potential variations in occupancy.

Measurement of the error made by each recorder in the collection of data was considered an integral part of the project. This task was approached through the series of redundancy counts. Four sites that represented traffic volumes from 16 to 47 vehicles/min were selected. It was hypothesized that, as traffic volume exceeded a certain threshold level, the accuracy of the individual recorder would decrease. In addition to measuring the amount of error in the counts, it was hoped that an estimate could be made of the threshold volume at which accuracy began to be significantly compromised. To this end, a single traffic recorder carried out the count at a site in his or her normal manner. In addition, two other counters split the traffic flow at that site (usually taking one lane each), thereby reducing the volume of traffic each had to monitor. The sum of these two partial counts was then compared with the count of the individual recorder.

STATISTICAL METHODOLOGY

Several different analysis techniques were considered to evaluate the various research tasks. Briefly, statistical techniques designed to test for differences between or among data sets were used to analyze the monthly, seasonal, and day-of-week occupancy counts, and simple linear regression was selected as an appropriate technique for exploring possible relations between occupancy and a number of other variables. The regression method used was a straightforward procedure that can be found in any basic statistics text. However, since very little research has been done in the area of monitoring and evaluating changes in occupancy over time, statistical procedures to accomplish this are not well established. Thus, a primary goal of this project was to explore various techniques for monitoring and evaluating automobile occupancy and to provide guidelines for future efforts in this area. The statistical procedures used in the study are discussed only briefly here. The statistical method used and many of the issues raised in such research are discussed in detail elsewhere (2).

Both parametric and nonparametric statistical tests were evaluated for use in this study of occupancy. The general distinction between the two is that parametric tests involve the use of parameters such as sample means and variances whereas nonparametric tests usually treat only the observations themselves. The primary statistical tests used in this study were the analysis of variance (ANOVA) test (a parametric test) and the chi-square test (a nonparametric test). Both of these tests are capable of evaluating several time periods or survey sites simultaneously to determine whether significant differences exist among the data samples. Significance levels of 0.01 and 0.05 were chosen for this study to indicate how strong the results were. In addition, a studentized range test, although rather obscure, was used to supplement the results of the other tests (3); for example, when the ANOVA or chi-square tests showed that significant differences did exist, the studentized range test helped to determine which days were contributing to the differences.

The sample size required for analyses of occupancy is often a question of concern for transportation engineers. The required sample size can be calculated for a survey of automobile occupancy by using accepted statistical methods. But the required sample sizes are almost always somewhat stringent for occupancy studies, usually because the differences of interest are quite small in comparison with the mean occupancy values. An alternative procedure that is much less conservative takes into consideration the fact that most surveys of occupancy actually count a very high percentage of the total population, i.e., total vehicle flow in a corridor. In some cases, almost 100 percent of the vehicles at a site are counted, and it does not seem reasonable to recount what are, in effect, the same people on successive days. In such a case, a finite population correction factor should be applied to the variance to allow the required sample size to be adjusted accordingly (4).

ANALYSIS RESULTS

The data file accumulated during the study consisted of a total of 657 records, one for each 2-h occupancy count. There were problems with data collection in the first 3 months, so the counts collected during that time were disregarded. For the monthly and seasonal analyses, a 202-record subfile (18 sites for 12 months with 14 counts missing) was used as the basis for the analysis. The 267-record day-of-week file consisted of data for 7 sites for eight weeks (two per site per quarter for a single year) in which 13 counts were missing. For most of the analysis, one full set of day-of-week counts per site per quarter (i.e., with no days missing) was used; this yielded a total of 140 records for that part of the analysis. Some within-month day-of-week analysis was done in which there were sufficient data for two weeks in the same month at a site. The data on time-of-day variation consisted of 48 records for 3 sites. During the fall, only the inbound direction of traffic was surveyed. During the spring, however, the outbound direction was added for 2 of the 3 sites; the third site was an inbound-only freeway off-ramp in the Seattle CBD.

There were a total of 73 records for the corridor analysis of occupancy. The number of records per corridor ranged from 7 to 19. There were 29 records for the analysis of the Seattle CBD cordon and 6 and 4 records for the Bellevue and Renton CBD cordons, respectively. The results of each analysis task are described below.

Redundancy-Count Variations

Before the data were analyzed in order to explore possible relations, patterns, or trends among sites or time periods, the quality of the data was evaluated by using redundancy counts. This was done primarily to determine the degree of variation in occupancy surveys as a function of rate of traffic flow. Four sites with volumes that averaged from 16 to 47 vehicles/min during the 2-h morning peak period were selected from the 18 monthly sites. At the sites that had volumes of 47, 39, and 26 vehicles/min, a two-counter team and one or more individual counters surveyed occupancy. At the site that had a volume of 16 vehicles/min—a downtown freeway off-ramp—three recorders, working individually, performed the survey.

When the statistical methods designed to test for significant variation between or among counts were used, no significant differences emerged for any of the redundancy counts. The differences in automobile occupancy were all less than 1.1 percent; the maximum difference for a single site was 0.013. These results demonstrated that, under a variety of conditions, variation in flow rate or differences in staff assignments at a site did not result in significant differences in the occupancy counts. This was interpreted as support for the generally high quality of the data and an indication that any variations that might be identified were not likely to have been caused by these extraneous factors.

General Variations

For all 18 sites in the main data file, average automobile occupancy for the year August 1977 through July 1978 ranged from a low of 1.108 persons/vehicle to a high of 1.403 persons/vehicle. Before the statistical analyses were performed, some general comparisons of the data were made to see if any trends or patterns emerged. By using the midweek morning-peak counts collected for the monthly and seasonal analyses, an annual average automobile occupancy was calculated for each site to serve as a basis for a first-cut comparison of various sites. These averages ranged from a low of 1.157 persons/vehicle on a suburban expressway to a high of 1.348 persons/vehicle on a freeway off-ramp in downtown Seattle.

When the sites were categorized by type of facility—i.e., expressway, arterial, or expressway ramp—none of the groups showed a pattern of consistently higher or lower average occupancies than the others. An ANOVA test of average automobile occupancy by the three facility types resulted in a failure to reject the null hypothesis, which means that the data did not support a conclusion that facility types differed with respect to average automobile occupancy.

Average automobile occupancy at these 18 sites was also viewed from the perspectives of varying traffic volumes, levels of transit service, and distances to the Seattle CBD. Three scattergrams were created by using these three variables as the independent variable and average automobile occupancy as the dependent variable. No visible relations emerged, and the R^2 for a simple linear regression ranged from 0.002 to 0.412, which indicated no significant relations.

Since none of these variables showed a significant or promising relation with average automobile occupancy, these lines of investigation were not pursued further. The analysis continued with the statistical evaluation of variations in occupancy by month, season, day of week, and time of day and analysis of occupancy in major corridors and at CBD cordon stations.

Monthly and Seasonal Variations

Of the 18 sites surveyed each month, all but one showed statistically significant differences among the monthly counts. In many cases, the cause of these differences appeared to be the fact that one or two months showed particularly high or low occupancy rates at an individual site and considerably less variation among the rest of the months. There were no consistent patterns of high or low occupancy rates for particular months over the spectrum of sites nor seasonal trends of high or low occupancy. Furthermore, when either urban or suburban sites were viewed as a group, no patterns emerged.

In many cases, there was considerable variation and the occurrence of highs and lows over the entire 12-month survey period. Yet no patterns emerged to suggest that occupancies varied in a predictable manner that might allow future occupancy rates to be reasonably estimated from a single count in a particular month. Figure 3 shows monthly data plots for an urban and a suburban site.

Day-of-Week Variations

Seven survey sites, including two expressways and five arterials, were selected for the day-of-week analysis. Three of the sites were suburban and four were urban. To explore day-of-week variations at individual sites, data that consisted of five-day counts taken in October 1977 and January, April, and June and July 1978 at each site were used. The analysis techniques were designed to test whether significant differences existed among the days in a single week at an individual site and, if differences did exist, whether there were consistent patterns.

Only one site showed significant differences among the days for all four survey months, and two sites showed no significant differences for any month. The remaining sites showed significant differences for some months and no differences for others. Where significant differences did exist, they appeared to be the result of particularly high or low vehicle occupancies on one or two days. Yet there were no consistencies to these patterns, either among months at a single site or among sites. At one site, for instance, in October Tuesday had the lowest occupancy and Friday the highest whereas in January the situation was exactly the reverse. The data plot in Figure 4 shows automobile occupancy by day of week for a single site during two different weeks. During one week occupancy was relatively constant, whereas in the second week Monday showed a partic-

Figure 3. Sample monthly data plot.

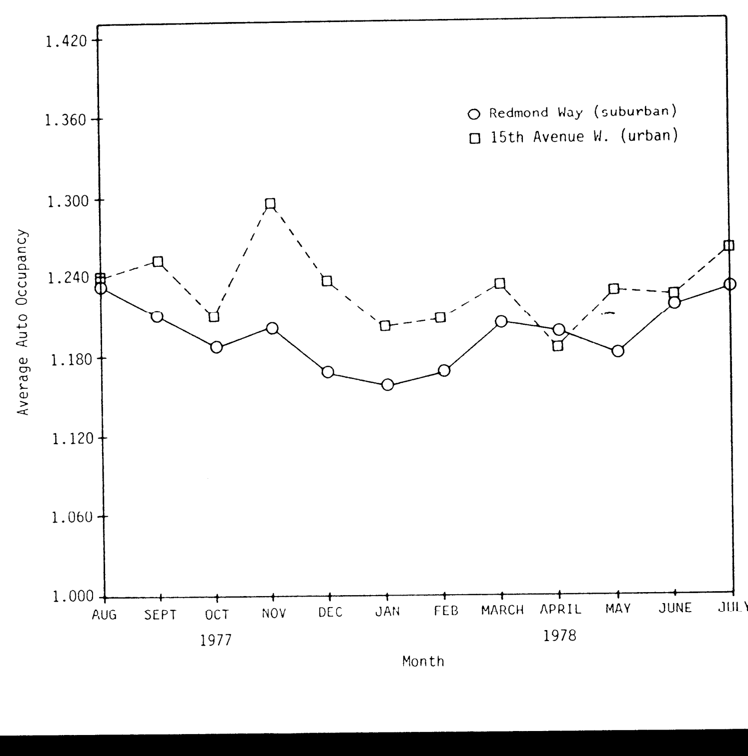


Figure 4. Sample day-of-week data plot.

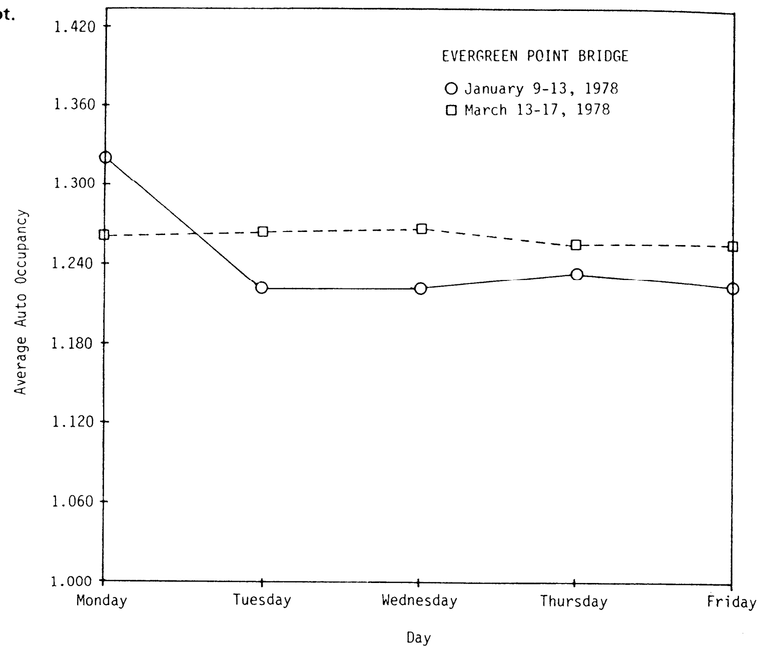
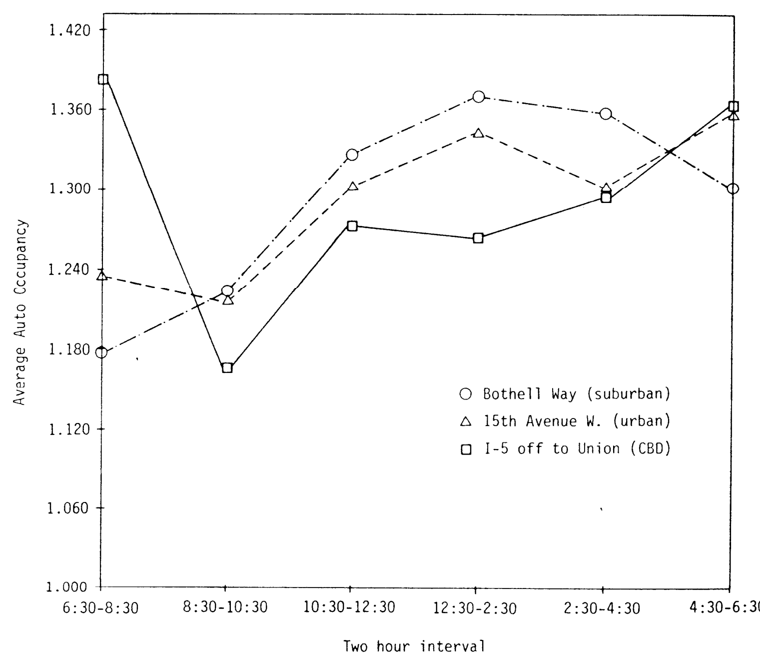


Figure 5. Sample time-of-day data plot.



ularly high automobile occupancy.

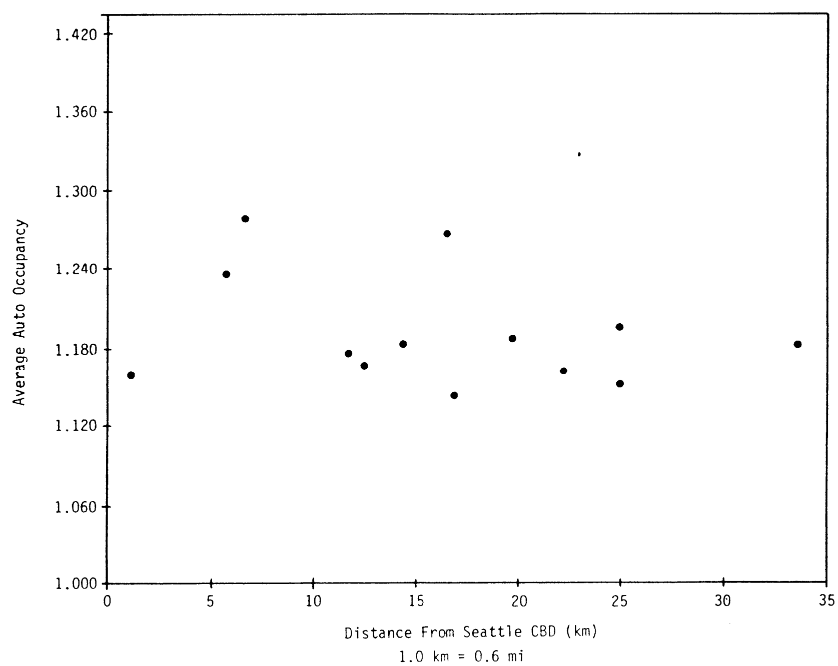
Several other avenues of investigation were also explored, but these yielded no more positive results. Viewing either urban or suburban locations as a group yielded no patterns among days, and there were no trends among the four seasons across the spectrum of sites. Where data were available, two five-day counts within a single month at a site were compared. In many cases there were no significant differences among the days for either week, whereas in other cases there was an aberrant day in one week or the other or both. Again, there were no consistencies among days that showed particularly high or low occupancies.

Time-of-Day Variations

The amount of exploration of time-of-day variations that was possible was limited by the small amount of data collected for this task. Figure 5 shows sample data plots for the three sites at which 6:30 a.m. to 6:30 p.m. time-of-day surveys were conducted; only occupancies in the inbound direction are shown. As can be seen, there was great variation among the three sites. At one site the morning peak period had the highest occupancy of the 12-h day whereas at another it had the lowest. There was additional variation at other times of day.

One valuable finding from these data is that, con-

Figure 6. Average automobile occupancy versus distance to Seattle CBD for I-5 South corridor.



trary to widespread belief, the morning peak period does not always exhibit the lowest occupancy of the day. This may have ramifications for future efforts to promote carpooling since it indicates that, in relation to other types of trip makers, peak-hour commuters may already be ride sharing to a relatively high degree in some locations. In addition, the considerable variation among the three occupancy patterns for the three different sites indicated that time-of-day variations are not consistent for different locations and that it would be difficult, if not impossible, to derive useful expansion factors for occupancy at various times of day.

Major-Corridor Variations

A major goal of the analysis of major-corridor variations was to determine whether occupancy varied in a predictable manner along corridors that lead from suburban areas into central Seattle. The four primary corridors—I-5 North, I-5 South, I-90, and WA-520—were selected, and one-time-only surveys of occupancy were conducted at every inbound on-ramp. The amount of data collected for these four corridors ranged from 7 to 19 records/corridor.

The primary technique used here was a simple linear regression of average automobile occupancy versus distance to the Seattle CBD. For the WA-520 corridor, the R^2 was 0.211; for the other three corridors, the R^2s were all less than 0.07. An overall regression of all corridor on-ramps versus distance yielded an R^2 of 0.036. These low values indicated that no linear relations existed between corridor occupancies and distances to the CBD. The data plot of automobile occupancy versus distance for the I-5 South corridor is shown in Figure 6.

In addition to these four main corridors, occupancy was surveyed at selected ramps along I-405, the primary north-south freeway route linking the suburbs east of Lake Washington. The length of I-405 was divided into three (sometimes overlapping) sections and, in a given section, either southbound or northbound on-ramps were surveyed. These divisions were made according to general travel patterns of I-405 traffic toward several routes leading to the Seattle CBD. As in the other corridors, no relations emerged between average occupancy and distance along the corridor.

Analysis of CBD Cordons

The stated purpose of the analysis of the CBD cordons was to determine occupancy rates at stations along the Seattle, Bellevue, and Renton CBD cordons. Because the counts taken for this task were one time only, no comparisons over time were possible. From the data records for each CBD (29 for Seattle, 6 for Bellevue, and 4 for Renton), overall average automobile occupancy along the cordon line was computed. This average value for the Seattle CBD was 1.300, which was considerably higher than that for either Bellevue (1.133) or Renton (1.188). There was also significant variation within an individual CBD: All but one of the counts for the Seattle CBD cordon resulted in values between 1.107 and 1.453, and there was an average value of 2.734 at a freeway off-ramp restricted to carpools and transit.

CONCLUSIONS AND RECOMMENDATIONS

The results of the study described in this paper are evidence of the lack of predictable relations, patterns, or trends found in the study data on vehicle occupancy. The task of investigating automobile occupancy at CBD cordons was designed primarily to determine automobile-occupancy rates at particular locations, and this was accomplished by selecting appropriate sites and surveying occupancy. The remaining tasks, however, were directed toward exploring variations in automobile occupancy over time or distance and trying to find explanations for any variations; in these areas, differences in occupancy were found to exist, but no patterns could be identified to explain the variations. This outcome proved extremely frustrating since it was felt that there must be clues somewhere in the wealth of data collected in the study that would help to explain the variations encountered.

Several possible factors were considered that might account for the lack of consistency in the data. The first factor is possible uncertainty in the accuracy of the occupancy counts. Although several redundancy counts were conducted to check for variations caused by the rate of traffic flow or individual recorder differences, these were not exhaustive and additional tests are needed before the question of the accuracy of the data can be entirely resolved. Factors such as the visibility of passengers and the potential for missing some vehicles may cause variations in the data. This is especially important in surveys conducted during the winter months when it is still dark during the morning peak period.

Assuming that the data collected for this study are accurate, no explanation has been found for variations in automobile occupancy among the 18 sites around the region. Since none of the variables investigated here—type of facility, traffic volume, level of transit service, distance to the CBD, or urban versus suburban location—showed a relation with average automobile occupancy, other possible explanations were hypothesized. Unfortunately, budget constraints precluded additional analyses that might have shed more light on the issue of variations and changes in automobile occupancy. Variables that were not explored in this study but that might hold promise for future efforts include the income level of the commuter shed for particular sites, which is admittedly difficult to measure in most cases, and characteristics of ride sharers in a corridor (whether they are co-workers, kiss-and-riders, and so on).

Aside from variations among the various sites, no consistent patterns were found in the time-series data over the 12-month period. One possible explanation relates to whether this was a realistic time frame for exploration of variations in occupancy. Although the study analyses made use of a large amount of data collected over a one-year span, one year may be too short a period in which to identify any longer-term trends in the data. The results of this study indicate that there are not predictable variations in automobile occupancy by day of week or by month or season. Yet it may be that occupancy is affected by and responds to longer-term changes in, for instance, regionwide economic or employment trends. To explore these possibilities, it is necessary to conduct a continuing survey of automobile occupancy over time.

In relation to what sites should be selected for occupancy surveys, evaluation revealed that 9 of the 18 sites chosen for monthly counts as the basis of this project could be eliminated from future surveys. This conclusion stemmed from a number of factors. At the outset of the study, there was some desire to attempt to establish, and to monitor variations in, a regionwide average automobile occupancy. Yet, after close analysis of the data gathered at the sites included in the project, it was concluded that it would be essentially impossible to calculate a value for regionwide automobile occupancy by using the methodology outlined here. Furthermore, such a value would be of only limited use in evaluating trends in carpooling.

The sites at which automobile occupancy is of interest are those at which, because of high traffic volumes, existing or expected future congestion, or special transportation considerations, there is an interest in monitoring changing commuting patterns. For instance, several of the 18 sites used in this project were outlying suburban expressways, expressway ramps, or arterials where volumes are relatively low, congestion is not a problem, and, because of their remoteness from downtown Seattle and other primary employment centers, there is relatively little potential for much participation in a ridesharing promotion effort. In addition, since no correlations were found between occupancy and either distance to the Seattle CBD or traffic volume, it is not necessary to include remote or low-volume sites for the specific purpose of providing balance over the total spectrum of sites. It was recognized that the areas of real interest are those where future changes, either in a particular corridor (such as institution of a peak-hour exclusive HOV lane) or in more general policies (such as parking restrictions in the CBD core), may affect the degree of ride sharing. It is at these locations that it will be important to try to assess the actual impacts of such changes.

Several recommendations can be made as a result of this study. To accurately assess changing commuting patterns, a long-term, continuing program should monitor carefully selected sites at regular intervals, perhaps monthly. These occupancy rates should be plotted regularly so that any variations can be seen in the context of changing external circumstances. In the Seattle area, 9 of the 18 sites have been chosen for an ongoing program in which occupancy will continue to be surveyed once each month at each site. Since no consistent day-of-week variations were found, the monthly counts can be taken on any weekday. One way of viewing these values is to calculate a moving average. For example, beginning at the time when 12 months of data have been accumulated, a 12-month average is computed; for each succeeding month, the earliest value is replaced by the most recent value, and a new 12-month average is computed. Plotting these values yields a 12-month moving average, which can often help identify longer-term trends by eliminating the interference of month-to-month or seasonal fluctuations. Another technique would be to average monthly occupancies into quarterly values for plotting and analysis purposes; as in the case of the moving average, this would level out shorter-term variations.

As discussed earlier in this paper, the relation between average automobile occupancy and other carpooling measures, such as the percentage of persons in vehicles with three or more occupants, should be kept in mind. Because of local conditions (such as the definition of a carpool for a local incentive program) or the characteristics of a particular location, one measure may be better suited to describe the situation than another. Furthermore, the percentage of persons who carpool tends to be a more tangible and meaningful value for most laypersons than average automobile occupancy.

This study recommends an ongoing program to continuously monitor automobile occupancy. In some cases, this is not feasible because of staff, financial, or other constraints. In these instances, however, it may still be of interest to attempt to assess the impact of individual programs to promote ridesharing or other changes in circumstances. To address this need, guidelines have been developed to aid planners in monitoring automobile occupancy at a limited number of locations for the purpose of evaluating specific programs. In such cases, it is necessary to conduct before-and-after surveys of automobile occupancy to help evaluate the effectiveness of the program. Although this research has shown that variations in occupancy rates may be irregular and apparently nonsystematic, a carefully conducted before-and-after survey may help reflect changes caused by a carpool-incentive program. A detailed set of guidelines for conducting surveys of automobile occupancy has been developed as part of this research project (5). Again, one must be careful not to automatically attribute any changes in occupancy to the carpool program.

One aim of future research in the area of variations in automobile occupancy should be to verify whether the results of this study apply in other metropolitan areas. Since nearly all of the factors that relate to levels of ride sharing can vary from one city to another, occupancy rates and their variability over time and at different sites may also be significantly different. Since analysis of automobile occupancy is a relatively new field of research, ongoing projects will be needed before the complex interactions among the variables can be better understood and explained. This will then enable engineers, planners, and policy makers to work together to address transportation problems in metropolitan areas.

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Georgia's Evaluation of Federal Highway Administration Procedures for Estimating Urban Vehicle Miles of Travel

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The once relatively obscure statistic of vehicle miles of travel has taken on a much higher profile with the advent of air quality standards and energy policies. It is probable that federal agencies such as the U.S. Departments of Transportation and Energy and the Environmental Protection Agency will use statistics on vehicle miles of travel in establishing future national transportation policies. In late 1977, recognizing the need for a uniform method of calculating estimations of vehicle miles of travel, the Georgia Department of Transportation contracted with the Federal Highway Administration to test the draft procedural manual, Guide to Urban Traffic Volume Counting. This paper outlines Georgia's testing procedures and presents a comparison between procedures in the Guide and the current method of calculating vehicle miles of travel. Statistical tests are reported, and the advantages and disadvantages of each methodology are evaluated.

This paper presents the approach taken by the Georgia Department of Transportation (GDOT) in evaluating the procedures described in the Guide to Urban Traffic Volume Counting, which outlines a methodology for estimating vehicle miles of travel. GDOT has for a number of years provided a statewide estimate of vehicle miles of travel. This statistic is based on traffic information collected by Georgia's coverage count program. In GDOT's testing of the procedures, data were collected as prescribed and were then compared with the data collected in the coverage count program.

This paper covers the experience gained in the project and recommends procedural modifications based on this experience (since the basis of the research is the determination of vehicle miles of travel, no SI equivalents are given except in certain general references to distance).

BACKGROUND

In Georgia, traffic data collection and reporting are primarily the responsibility of GDOT. This applies to both rural and urban areas. However, some local governments do collect a limited amount of data, primarily for traffic engineering applications and to supplement annual traffic data provided to them by the coverage count program of GDOT.

GDOT currently operates 61 continuous-count and 96 seasonal-control stations throughout the state that provide trends and factors used in expanding 24-h coverage counts to estimates of average daily traffic.

Evaluation of Educational Treatment for Rehabilitation of Problem Drivers

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A unique rehabilitative treatment for improving the performance of problem drivers was developed and evaluated in Florida. Entitled Responsible Driving, the treatment places emphasis on group discussion of concepts and principles derived from transactional analysis, a theory of personality developed by Eric Berne, M.D. In order to test the effectiveness of the treatment, hearing officers from five Florida cities randomly assigned 432 problem drivers to an experimental treatment group, a defensive driving course group, and a control group. All subjects had lost their driver's licenses and were attempting to obtain a temporary license for some hardship reason. Safety officers from the Florida Highway Patrol taught both the experimental and the defensive driving course. In addition to written pretests and posttests for study subjects, the driving records established by each were followed for 12 months. Results showed that the experimental treatment was significantly more effective ($p = 0.05$) than no treatment in reducing the number of traffic collisions and the number of convictions for moving traffic law violations. The defensive driving course was not significantly different from any group at $p = 0.05$. Although the findings of this study may be questioned due to small sample size and the lack of rigorous supervision in its conduct, there was evidence to support the use of the new treatment for helping problem drivers improve their driving behavior. It is recommended that this treatment be evaluated in a larger, more rigorous study.

The majority of drivers will obey traffic laws most of the time either because they are aware of the value of the laws or they are afraid of getting caught and facing the consequences. However, a small percentage of drivers repeatedly disobey traffic laws, or frequently become involved in collisions, or both.

In attempts to modify errant driver behavior, highway safety authorities have used fear tactics, such as warning letters, fines, license suspension and revocation, and imprisonment. These methods have had an effect on some so-called problem drivers (1, 2). However, the authorities found that fear tactics did not work for other problem drivers and even appeared to have a negative effect on them (3, 4).

Therefore, other, less punitive measures have been implemented. These measures have included attempts to educate problem drivers by improving driving knowledge and skill. Other measures have attempted to improve the attitudes of problem drivers or have dealt directly with the maladaptive behavior. Each of these treatments has demonstrated short-term success when compared with results of punitive measures (5, 6, 7, 8, 9, 10). Evidence of long-term effectiveness does not exist (11). One reason may be that these measures attempted to treat only a part of the problem. Driving behaviors are formed by past experiences, present conditions, and future expectations. These, in turn, are based on existing knowledge, skills, thoughts, attitudes, and emotions.

Research in the field of human factors in traffic safety in particular and in the field of human behavior in general has pointed the way toward a more comprehensive understanding of human actions. Although many studies have attempted to show the relationship between certain character traits and driving (12, 13, 14, 15, 16, 17), the major conclusion with the most validity is that maladaptive driving habits and overinvolvement in traffic collisions are manifestations of drivers' life-styles (12, 18, 19, 20). This conclusion was further substantiated by Shaw and Sichel (21). These researchers found that total personality, rather than any one trait, was the significant predictor of how a person drives.

Another conclusion which is pertinent to helping a person make a more permanent change in driving habits has been uncovered in human behavior research. This conclusion is one of the major assumptions upon which the theory of operant conditioning rests (22) and was expanded to become a major aspect of transactional analysis, or TA (23, 24, 25). In effect, this assumption states that a person does not act without a payoff. According to TA theory, this payoff is a feeling, either real or artificial, positive or negative, conscious or subconscious. Most habitual behavior patterns, which appear to be maladaptive to an observer, have more positive than negative value to the individual performing the behavior. Every behavior is the end result of an internal decision-making process of thoughts and feelings.

Therefore, if an attempt is made to help a person deal more effectively with only one aspect of this process—e.g., thoughts (knowledge or attitudes), feelings, or actions—the person will need to learn how to deal with the remaining aspects. This reduces the probability that long-term change will be effected. Old habits are comfortable; new behavioral patterns are uncomfortable. Long-term changes can result only if the new patterns become internalized. Internalization of new behavior patterns can occur over a short or a long period of time, depending on an individual's willingness to learn and readiness for change (level of motivation).

A new treatment for the rehabilitation of problem drivers was developed based on these ideas (26). The treatment was tested in three Florida cities. Based on the positive results of these tryouts (27), a larger study compared the new treatment with a traditional treatment (28).

PURPOSE OF STUDY

The primary purpose of this study was to compare the short-term and long-term effectiveness of two treatments on the driving behavior of problem drivers. The two treatments were the National Safety Council's Defensive Driving Course (DDC) and the new treatment, referred to as Responsible Driving. DDC is primarily a knowledge-based course using lectures, films, and other media as the major instructional techniques. The experimental treatment focused on helping participants learn to accept responsibility for their actions, especially while driving. Using group discussion, role playing, decision-making techniques, the lecture, films, and other media, participants were invited to express their feelings and ideas while learning to increase their self-awareness, driving knowledge, and, above all, willingness to perform in a responsible manner while driving.

METHODOLOGY

All subjects for this study were selected from Florida's population of problem drivers who requested and received a hearing from a hearing officer regarding their

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Driver Education for Stress Conditions

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A set of driver performance training activities has been developed to prepare drivers to handle a vehicle under such stress conditions as tire failure, skid situations, off-road recovery when one or more wheels drop off pavement, and to properly steer vehicle, to evade sudden impending dangers, and to brake the vehicle without losing control. As this paper points out, when these activities are learned and practiced, improvements occur in a driver's ability to operate a vehicle and to respond to stress conditions with a high degree of success. In addition, reductions in accidents and property damage have also taken place.

The program described in this paper was developed from information obtained through a search of the literature and through experiences gained by participating in training programs previously developed by such organizations as Liberty Mutual Insurance Company, General Motors Proving Ground, and the National Safety Council.

For many years, the Liberty Mutual Insurance Company has provided information via films and workshops concerning the ability to control a vehicle in various skid situations (1). General Motors Proving Ground first developed a series of activities that were aimed at improving skills of drivers in handling emergencies (2). The National Safety Council has for many years conducted Winter Driving Techniques Workshops at Stevens Point, Wisconsin (3).

Others have conducted training programs that have