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# DETERMINATION OF VEHICLE OCCUPANCY FOR SMALL AND MEDIUM SIZED AREAS

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## ABSTRACT

Recent revisions to transportation system performance monitoring techniques have resulted in the need for data related to vehicle occupancy, or the number of persons carried in all types of highway vehicles. Rather than a continued focus on the number of vehicles moved through a corridor, measurement of the number of persons moved and speed of movement is now required in the mobility management process and congestion management systems. In addition, many strategies to improve transportation system performance have the goal of increasing vehicle occupancy. The result is the need for increasing amounts of vehicle occupancy information.

During 1996 and 1997, the Florida Department of Transportation undertook a statewide study of methodologies to efficiently collect and analyze vehicle occupancy. Over 2,000 hours of data collection at 21 different types of roads. Data analysis studied variation by type of facility, travel lane, direction, hour throughout the day, day of the week, and month of the year. Alternative methods of collecting data, observation locations, dealing with commercial vehicles, overhead observation points, and similar characteristics were included. Automated methods and use of alternative databases were surveyed.

This paper presents a brief summary of study findings, oriented to the small to medium sized area. Overall study findings useful in evaluating how to establish an overall vehicle occupancy program, alternative methods of data collection, as well as techniques to determine vehicle occupancy for single roadways are included. The paper includes best practice recommendations for vehicle occupancy data collection, analysis, and use for small and medium sized areas.

# DETERMINATION OF VEHICLE OCCUPANCY FOR SMALL AND MEDIUM SIZED AREAS

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), and its continuation, the Transportation Equity Act for the 21st Century (TEA-21), revisions to the joint FHWA/FTA urban transportation planning regulations, and individual state and local area efforts to monitor transportation systems performance have resulted in new data requirements. Transportation planning agencies are now monitoring travel trends and developing multimodal transportation improvement plans at both the regional and local level. Rather than a continued focus on the number of vehicles moved through a corridor, measurement of persons moved and speed of movement is now required for the mobility management and congestion management processes. In addition, many strategies to improve transportation systems performance have the goal of increasing vehicle occupancies, or the number of persons individually or collectively carried in all types of highway vehicles.

During 1996 and 1997, the Florida Department of Transportation undertook a statewide study of methodologies to collect and analyze vehicle occupancy. Alternative methods of collecting data, observation locations, field procedures, how to deal with commercial vehicles, use of roadside or overhead observation points, and similar characteristics were included.

This paper presents a brief summary of the findings of the overall study and information useful in conducting a vehicle occupancy data collection and analysis effort. The paper is oriented to the small and medium sized area, includes a discussion of alternative data collection methodologies, and concludes with “best practice” recommendations.

## STUDY FINDINGS

The subject study included the collection of more than 2,000 hours of vehicle occupancy data from a series of 21 individual sites throughout Florida, ranging from two-lane rural routes to four and 6-lane urban arterial routes. Basic data collection was accomplished by the roadside / windshield (personal observation) method during daylight hours by lane and direction, for five consecutive weekdays. Four sites were observed once each month for a year, to determine the temporal changes in vehicle occupancy over a year's time.

### Hourly Variation

Vehicle occupancy rates generally start low in the early morning, increase after the morning peak period, remain level during the middle of the day, drop around 5:00 P.M., and reach a high point around 6:00 P.M. This may be explained by the higher percentage of commuter traffic in the morning, business and lunch traffic during the midday, commuters returning home around 5:00 P.M., and recreational and shopping trips in the evening.

### Lane Variation

Vehicle occupancy rates vary among lanes (i.e., inside, middle, and outside) and generally do not equal the population mean for the entire roadway site. Several factors such as traffic characteristics, difficulty of seeing the inside lanes, or the surveyors' skill may have contributed to this result. This finding suggests that estimating vehicle occupancy rate using the data collected from any single lane would not be accurate. Also, there is no uniformity concerning which lanes have higher vehicle occupancies.

### Directional Variation

Directional variation was also found to vary by site, as expected. The vehicle occupancy rates obtained from different directions do not always represent the average value for the site. A negative correlation between traffic volume and the occupancy rate was also found at sites that mainly serve commuting traffic. This means that vehicle occupancy drops as traffic increases, which can be explained by the larger percentage of commuters in the higher vehicle streams.

### Daily Variation

It was found that distributions of occupancy rates vary by day throughout the week. The daily average vehicle occupancy rates observed on some days were closer to the five-day average value than were other days of the week. Vehicle occupancy rates on Fridays were nominally higher. The occupancy rates on Tuesdays and Wednesdays were generally lower than other days during the same week. The best day for collecting data may be Thursday. Mondays and Fridays should be avoided for vehicle occupancy data collection.

### Monthly Variation

For the Florida data, occupancy rates observed in March and July were higher than other months of the year, which might be accounted for by travel involving the spring break and summer vacation at schools. The occupancy rates observed in September, November and December were lower than other months of the year at all four sites. However, conclusions from this phase should consider the tourist and part-time residential characteristics of travel within Florida.

## USE OF CONTROL DATA

Vehicle occupancy is a derivative, or results-oriented variable. Conditions affecting vehicle occupancy at a particular location includes the number and characteristics of commuters, patterns of ridesharing, external factors affecting the amount and character of vehicle usage (fuel shortages), land uses influencing the trip, and similar matters. The conditions that result in a particular vehicle occupancy cannot be determined solely by observance of passing vehicles at a data collection site. Much like early estimates of trip origin, a pure vehicle occupancy study, or one adequately explaining the background influences would require detailed interviews with the vehicle occupants.

In addition, the reasons for a particular trip and resulting vehicle occupancy can change over time (for example, vehicle occupancy on rainy days would be expected to be higher than on clear days). Similarly, vehicle occupancy on routes serving areas of concentrated employment, or school destinations where multiple-person commuting is the norm would be higher than the vehicle occupancy from a high-type "executive" subdivision, or to areas of concentrated high-economic employment.

Initially, it was thought that, similar to traffic volume counting, a "control station approach" would reduce the cost of obtaining vehicle occupancy. In this method, data would be collected at one or more sites for a full day, to allow factors to be determined that would subsequently be used to adjust short counts obtained at other sites to an all-day average, or another hour of the day. It was also hoped that sites from similar roadway types or geographic subareas could be grouped together, so a particular control station count could represent multiple sites, and that annual average vehicle occupancy (yearly) could be determined using factors derived from the annual site measurements. Findings and conclusions resulting from this phase of the study represent a major caution for those using the control station approach. The analyst must ensure that travel conditions resulting in the particular vehicle occupancy at a control station represent the conditions at the other station(s) to be adjusted using the control data. This is not an impossible task, but caution and common sense are required in applying particular control station vehicle occupancy data to multiple locations, or to roadways with different characteristics.

Use of control station data to adjust subsequent short counts at that station is very appropriate. For example, it is not likely that the character of traffic at a particular site will change drastically within short periods. Control station adjustment factors to be used in future data determinations at that site will result in economy of effort over a several-year data collection effort, or until some external factor results in a major change in the character of traffic.

## TAILORING DATA COLLECTION FOR PARTICULAR PURPOSES

Initial decisions for vehicle occupancy studies involve the desired survey period, the anticipated usage of the data, the characteristics of the study area, and the type of vehicle to be included, as discussed in the following sections.

### Peak Period

Morning and evening periods of peak traffic flow are normally required for traffic engineering or alternative mode investigations. If peak-period vehicle occupancy is needed, then obtaining the data during the specific period is best. As discussed, appropriate vehicle occupancy control data can be used to adjust other counts for peak-period vehicle occupancy. Vehicle occupancy control data also reveals when the peak period for vehicle occupancy occurs, although this will normally be during late afternoon.

### Average Daily Vehicle Occupancy (AVO)

The first step in determining average daily vehicle occupancy is to define the period to be averaged. For example, the "average day" for vehicle occupancy may be defined as a full 24-hour day, daylight hours only, average weekday, or an average for a full week (including weekend days), or other combinations thereof. A short vehicle occupancy count can be adjusted to represent an "average" daily condition, but the adjustment must be based on representative control data for the total average time in question.

### Average Annual Vehicle Occupancy (AAVO)

Average annual vehicle occupancy (AAVO) represents the yearly average for a site, taking into account the seasonal change in vehicle occupancy. Accurate determination of AAVO is more complex, requiring data on how vehicle occupancy changes over a year's time. It is not likely that the analyst will have control data for annual conditions for a particular location so a substitute must be found. In critical locations the analyst may wish to take short counts over a year's time (same day of the week, same week of the month, avoiding unusual weather or traffic flow conditions, etc.) to determine the annual change for the area in question.

### Daylight or Full 24-hours

This seemingly elementary question should be determined early. Of course, as the collection of vehicle occupancy data requires determination of the number of occupants, the observer must be able to see into the vehicle. Special lighting that might be provided for data collection purposes could be dangerous to vehicle operators and is not normally used for vehicle occupancy studies. If full 24-hour data is required, then counts should be made at locations where existing roadway lighting allows proper observation. Such locations include lighted roadways, ramp terminals, intersections, etc.

An interesting question is why nighttime vehicle occupancy would be needed. If the vehicle occupancy data is to be used for congestion management, measuring mode shifts or similar purposes, daylight-hour or peak-period data should suffice. Exceptions might be locations where early nightfall or late morning darkness makes full data collection for peak periods difficult. In these cases, adjusting a later (partial) count can represent the full “day travel” period.

### Areawide, Corridor, or Single Roadway

If the data is to serve a corridor study, sufficient sites should be chosen along the corridor to cover all areas having different travel characteristics. Data collection methodologies for a single roadway corridor are similar. For area coverage, sufficient sites should be selected to cover all routes anticipated to exhibit different travel characteristics, different lane arterial, local streets, etc.). Although every major route may not have to be counted, in smaller areas this can easily be accomplished.

### Passenger Vehicles or Total Vehicles

Before starting data collection, the analyst should specify what types of vehicles are to be included. A ranking of vehicles for determination of vehicle occupancy includes the following: automobile, light (passenger) truck, van, motorcycle, transit bus, school bus, charter bus, large (commercial) truck, and bicycle. Pedestrian counts may also be included for determination of total person travel. All these modes have differing degrees of importance, depending upon the study or use of the data. For normal vehicle occupancy purposes, data should be collected for the first four types: automobile, light truck, van, and motorcycle. In addition, transit buses are often included. While the remaining categories are important, they are not normally included in studies of vehicle occupancy.

### “Before and After” Studies

Vehicle occupancy is frequently required to determine the performance of certain types of improvements. These “before and after” studies involve measuring the vehicle occupancy before the improvements are made, followed by the "after" element following the improvements and when conditions have stabilized. Obviously, “before” data should be collected before the condition being examined is established, or before any construction begins. Both the before and the after study should be conducted at comparable times representing normal conditions, or when conditions are sufficiently stable to show the physical change in the mode being studied, as opposed to some change occurring from external conditions. It is also worthwhile to collect data from a control route, external but parallel to the study route, to show how overall conditions may have changed during the survey period.

# STUDY METHODOLOGY

Vehicle occupancy is normally determined by manually counting the number of vehicles and the number of vehicle occupants passing an observation point over time. Because vehicle occupancy is a more stable variable than vehicular volume, there are alternative data collection methodologies. A valid determination of vehicle occupancy can be based on short observation intervals, although the data collection period should desirably be within the period of interest (e.g., peak hours, etc.). Counts of one to two hours will produce data with sufficient accuracy and precision for most purposes. Counting both directions and all lanes is important.

Tuesdays through Thursdays are normally adequate for data collection. Mondays and Fridays should be avoided. Data should not be collected during periods of inclement weather, due to the possibilities of a biased sample. For a rule of thumb, if short counts are to be made, counts during the midmorning to mid-afternoon period are adequate for most purposes.

Although the traditional (roadside / windshield) observation method is simple, economical, and adequate, there are several alternative methods as discussed in the next sections.

## Roadside / Windshield Survey

The roadside / windshield survey is the simplest and most reliable method of vehicle occupancy data collection. This method requires stationing an observer(s) near the roadside edge, who then counts and records the number of vehicles and the number of their occupants passing the observation point during the survey.

No special, expensive, or high-technology equipment is required, and a high sampling percentage can normally be obtained. Use of electronic intersection count boards increases accuracy, results in better recording and faster data transfer. Nevertheless, if these devices are not available, a clipboard, preprinted forms, a pencil, and a watch are all the observers require.

One observer per lane should normally be used (except very low volume roads). A trained observer can accurately record data from about 800 vehicles per hour. If anticipated lane volumes are higher, a sample should be taken. Use of two observers per the same lane is not recommended due to the difficulty of communications between them about which vehicles each should count. Data recorders should be instructed not to guess. If they cannot see the number of occupants, they should not try to estimate them. Unlike traffic counting, the accuracy of a vehicle occupancy count is not affected by missing a few vehicles.

Occupancy data for regular transit vehicles may be available from the transit agency, but can also be obtained by several methods. One is to prearrange to have the vehicles stop when flagged by an observer, who then boards the vehicle and makes a quick count of passengers. Charter buses represent a more difficult problem. Sometimes the charter agency will cooperate, but the problem arises because it is not usually known when a charter bus will pass by, and the name of the company operating the vehicle may not be readily apparent. Counting these vehicles, with a subsequent assumption of the number of occupants, may be sufficient. Large trucks may have two occupants, but stopping them for an occupant count is usually impossible. However, missing these vehicles will not significantly bias the sample.

## Field Data Collection Methodology

In the selection of vehicle occupancy data sites, make sure that each lane is clearly visible and that the vehicles in the different lanes can be distinguished from each other. Field check each site before data collection begins to ensure that the site is suitable from an observation and safety perspective and that it is suitable for the placement of traffic counters. On arterial streets, mid-block locations should be chosen for data collection to avoid the interruption of traffic due to traffic signals and turning movements at intersections or interchanges. In addition, selection of a mid-block location should result in a greater clear zone for observation and yield better data. The longer that an observer can view a vehicle, the better the data will be. Vehicles with passengers in the back seat often require more attention to determine the occupancy. A good view from the side of the vehicle often allows confirmation of the number of people in the back seat.

For high volume locations in urban areas, it is recommended that a police officer be present at the site to ensure that the survey does not cause a traffic problem. Even with advance notice being given to all interested agencies, experience has shown that data collection activities at a site without an officer present will attract other officers who require an explanation of what is happening. This disrupts the count and causes a loss of data.

## Use of Crash Data

Vehicle occupancy determinations have been successfully extracted from vehicular crash (accident) records, and a trial of the method was conducted as part of the overall study. In this method, the number of occupants per vehicle is determined from crash data using a computer analysis. While additional investigation is warranted, this method holds promise for an economical method of determination of vehicle occupancy rates. Better results would be expected for large area determinations, route studies, or similar applications where a larger data sample can be obtained. Data derived from this method, however, does not appear to provide sufficient accuracy for corridor studies or for specific before and after studies. Shortcomings also include the age of the crash data (availability of crash data typically lags the year of collection by two years) and potential differences between persons who have vehicular crashes as opposed to the entire population.

## Video Recording

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This method requires the use of video cameras, strategically placed to record vehicle occupancy data with subsequent manual or possibly the use of machine vision technology to reduce the data. The method requires complex equipment, and has many shortcomings of the roadside/windshield survey method such as inadequacy of the method during darkness. Overall, the method does not seem appropriate for widespread usage, unless the equipment is used to collect other data, and the vehicle occupancy can be determined as an “extra”.

### Carousel Method

The data collection effort verified a particular problem on high-volume, multi-lane facilities. The roadside observer probably cannot stand close enough to the roadside edge (due to police or other safety regulations) to be able to see into the vehicles. In addition, survey efforts showed that observing from overhead locations is not often adequate, because the observers cannot see into the back seat area of vehicles.

An alternative method has been developed by which observers in automobiles that move with, but slower than the traffic flow observe vehicles and their occupants. The vehicle is driven along a facility between intersections or interchanges with the observers recording vehicle occupancy data for vehicles in the traffic stream. At the end of the site, the driver returns to the starting point and starts a second run. Hence the term “carousel” method.

### Adjustment of Data

As noted previously, the type of vehicle occupancy data to be collected and analyzed depends on the needs of the study. Vehicle occupancy data collected with short counts (one to two hours) results in sufficient accuracy for most transportation planning requirements. With appropriate control counts, a short count can be adjusted for another period, or another site. Because vehicle occupancy is a results-oriented variable, external factors should be carefully considered in choosing control stations. Once control counts are prepared, short counts result in significant economy, particularly in widespread applications.

## RECOMMENDATIONS

The precision of required vehicle occupancy data should be correlated to the anticipated usage of the data. More precision is required for “before and after” studies, less is required for corridor studies (except that different characteristics of the corridor should be distinguished), and even less precision is required for area-wide systems performance determinations. Therefore, the following overall methodologies are recommended:

### Before and After Studies

For before and after studies, the condition to be measured and the necessary accuracy should be determined with a specific study design prepared for the particular effort. Data collection should be by the roadside/windshield method, or by an alternative method as discussed previously. Control data should not be used to adjust short counts. The entire evaluation period should be counted, with sufficient counts obtained to ensure statistical stability and accuracy.

### Corridor Studies

For corridor studies, sufficient locations along the corridor should be chosen to fully represent all traffic characteristics of the corridor roadway(s). Control data may be used if conditions warrant use of adjusted short count data.

### Areawide Studies

Areawide studies may use control-adjusted data or surrogates obtained through other methodologies. For an areawide traffic volume monitoring program, it would be logical to initially obtain vehicle occupancy information at each of the volume count stations. For an adequate program, a sample of major arterials and collector streets should be chosen. Developing area control stations for these roadways may be possible, but again, caution should be used to ensure that the control stations represent the sites to be adjusted. Lacking this approach, a one-day control count should be obtained for each site.

Obtaining monthly counts at an annual site(s) for at least one full year may also be desirable, to allow determination of long-term trends. Once control data has been obtained for these sites, short counts can be used to obtain the subsequent data.

An area may wish to investigate whether vehicle crash data is sufficient to determine area or sector vehicle occupancy. This can be accomplished by obtaining the crash data, calculating vehicle occupancy, and comparing it with data obtained through normal count methods. As noted, one shortcoming of this method is the age of the traffic crash data when it can be made available for other uses.

## CLOSURE

For transportation monitoring and evaluation purposes, vehicle occupancy has become an essential variable. This will allow the analyst to determine measures of person throughput, as opposed to simply describing vehicular flow. Person throughput is a meaningful performance measure, as, with volume flow and measures of travel time, it allows a much more meaningful description of the function of a transportation corridor.

The Florida Department of Transportation should be recognized for its efforts to improve the collection and processing of vehicle occupancy information, and for its development of transportation performance measures.  However, the opinions expressed in this paper are those of the authors and do not imply endorsement by that agency or others.