Mode Split at Large Special Events and Effects on Air Quality

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In the past few years, the scope and number of large special events, such as concerts and sporting events, have increased. Large special events are being viewed as a means of economic development, that is, as an attempt to bring in spectators from outside the region to obtain tourism dollars. Some cities are planning large special events that may attract as many as 100,000 spectators. Little published material is available applicable to the planning of large special events, especially in the areas of mode split (the mode of travel to the event) and the air quality impacts of these large events. A study was recently performed in nine large metropolitan areas nationwide to gain further knowledge of the impact of these events. The data collected were analyzed to derive conclusions and recommendations for assisting officials in planning of large special events. Analysis of the data revealed that average automobile occupancy for weekend events is much higher than on weekdays; automobile occupancy for higher-priced events is significantly lower than for lower-priced events; automobile occupancy at Western U.S. sites is much lower than at Eastern and Midwestern U.S. sites; transit usage where regularly scheduled special transit service is available is much higher than where charter or nonscheduled special transit service is provided; and transit fares have a significant impact on the transit mode share. Vehicles attending large special events can have large impacts on air quality. If resources become available, a model to be used as a tool for planning special events should be developed.

In the past few years, the scope and number of large special events, such as concerts and sporting events have grown. Many concerts are now being held in large outdoor stadia, whereas 10 years ago they were held mainly in medium- and small-sized indoor arenas. These special events have necessitated using the large stadium or large outdoor setting, to accommodate more spectators in an attempt to recoup the costs. Some cities, including Denver, have sponsored or are sponsoring large special events, such as automobile races, that are expected to attract as many as 100,000 spectators. In addition, many cities are vying for major league sports teams, with the promise of new stadium sites to accommodate the specific sport.

Little material has been published analyzing large special events. In fact, a computer literature search using keywords such as "special events" and "air quality" did not turn up a single study or report on this issue (*1*). Little, if any, work has been done to analyze large special events in terms of mode split or the mode of transportation people take to get to the event. Even less analysis has been performed on the air quality impacts of these events. This study, which was performed in nine large metropolitan areas nationwide, is aimed at collecting and analyzing data pertaining to the mode of transportation people take to get to large special events, evaluating the impact of the large event on air quality, and deriving conclusions and recommendations aimed at improving traffic flow to and from large events.

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Various problems arise from lack of information to plan for large special events. A large sudden influx of automobiles can grind the surrounding roadway network to a halt. This traffic congestion also is directly correlated to air quality; not only is the air quality in the immediate vicinity of the special event site impacted, but air quality at points away from the site can also be impactd by the effects of congestion as well. For instance, a Denver Broncos' football game, which attracts more than 75,000 fans on a given event day (usually Sunday), can generate over 4 tons of carbon monoxide (CO) and over 800 lb of hydrocarbons alone in the area within 1 mi of the stadium. Total pollutant emissions from this crowd region-wide can be as much as 40 tons of CO and 4 tons of hydrocarbons (HC). These impacts can be exacerbated if the event is held on a weekday.

Because of the fiscal constraints of this study, the number of sites sampled is relatively small and should not be considered as a representative cross section of the entire United States. Where possible, both weekday and weekend samples were taken at the same site. This was possible at the Denver and Cleveland sites. Sufficient samples were taken to enable grouping of the data, such as by weekend and weekday, by automobile and transit, etc., to attempt to derive general conclusions regarding large special events. Further study is needed to reduce any large variance in the data. Where possible, local information should replace the averaged information presented here.

DATA COLLECTION

Baseball and football games and large concerts were surveyed to obtain the necessary data. Nine metropolitan areas were chosen for this analysis. Figure 1 shows the metropolitan areas sampled for this study. The metropolitan areas were chosen to attempt to obtain a nationwide distribution of sample sites, and to obtain equivalent samples from each of the three United States regions (East, Midwest, West). Two sites, Denver and Cleveland, were sampled for both weekday and weekend events. Automobile occupancy information was collected on-site; transit information was obtained from the transit agencies serving the event site. The data collection phase started in July 1987 and was completed in July 1990.

Information gathered includes the attendance at the event, the day of the week of the event, automobile occupancy, and

- Baltimore
- Chicago
- Cleveland
- Denver
- Detroit
- Kansas City
- Los Angeles
- New York
- St. Louis

FIGURE 1 Metropolitan areas sampled.

transit patronage, as well as factors that could influence mode choice, such as parking costs, ticket prices, availability of transit, and transit fares.

In order to obtain average automobile occupancy, at least 100 automobiles entering the parking areas at the event site were surveyed. This sample was determined to be a 1 percent sample, which results in an error of ±5 percent. Transit agencies were surveyed to obtain information on transit ridership and level of service to the events. Event sponsors were surveyed for additional data, such as charter bus ridership to the event and ticket and parking price information. Arrival times were tallied to determine the distribution of arriving vehicles.

DATA SYNTHESIS AND RESULTS

The data collected have been synthesized into an electronic data base and are being analyzed. Two-sample *t*-tests and multiple sample correlation tests were performed on the data to determine correlation among certain data elements. Information has been categorized into weekends versus weekdays, and various levels of parking and ticket costs as well as type of transit service (public versus charter) were tested for correlation with automobile occupancy and transit usage.

Distribution of Arrivals to the Event

Figure 2 shows the distribution of automobile arrivals to the event site. The reference lines on the figure show the cumulative percent of arrivals at the interval within 1 hr of the start of the event. In some cases, this can mean as many as 10,000 automobiles arriving in 1 hr. Translated into highway capacity equivalents, this is the same as 5 lanes of freeway, or 15 lanes of arterial roadway. This second equivalency will serve to form a basis of this analysis, because most stadium facilities use the arterial roadway system to access the site, rather than direct freeway access. Because 15 roadway lanes is a large amount of capacity to be supplied, the access roads to the stadium can easily become overloaded before the start of the event and after the event, as well.

In the case of the Denver Broncos and their event site, Mile High Stadium, Figure 3 shows the roadway network accessing the stadium and the available number of arterial traffic lanes. There are 10 arterial traffic lanes provided. In the hour preceding the start of the football game, 10,000 automobiles (plus 200 buses) create a volume-to-capacity ratio

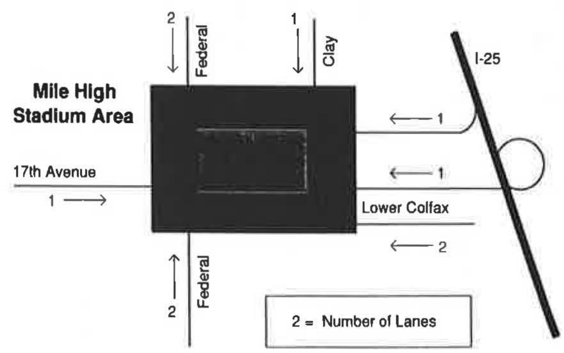

FIGURE 3 Access roads to Mile High Stadium.

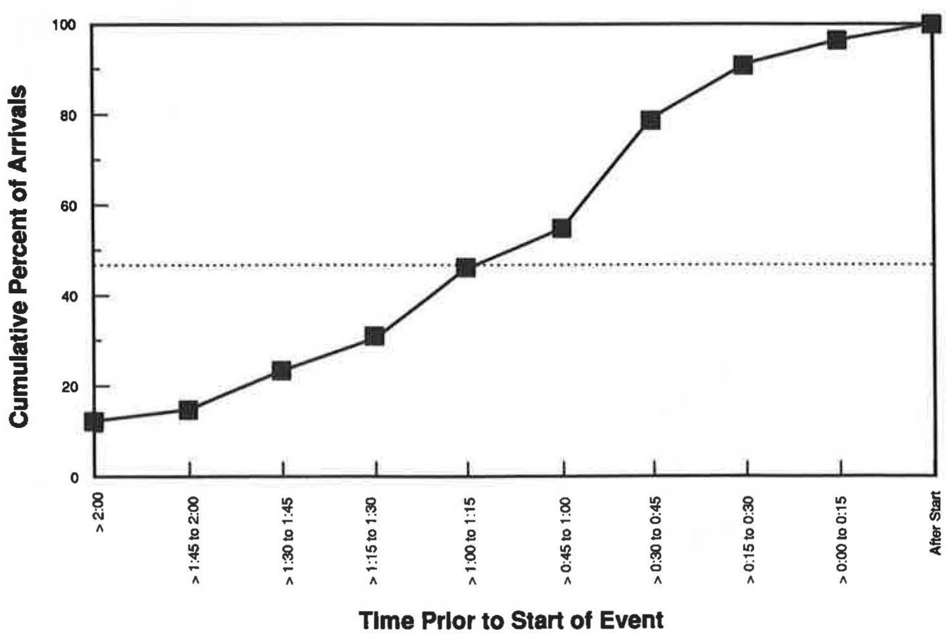

FIGURE 2 Cumulative percent of arrivals by time of arrival.

of 1.40, resulting in speeds in the area within a 1-mi radius of the stadium averaging between 10 and 15 mph. Using automobile emission factors supplied by the Colorado Air Pollution Control Division (from EPA's MOBILE 4 computer program), this translates to 4 tons of CO and 800 lb of HC in the stadium vicinity alone. Assuming the average eventgoer travels 10 mi at an average of 30 mph to attend the event (a liberal assumption), the total number of vehicles attending a Broncos' football game can produce as much as 40 tons of CO (based on an average CO emission rate of 15 grams per mile per vehicle) and 4 tons of HC (based on an average emission rate of 1.5 grams per mile per vehicle). These figures can be doubled if the game is held on a week night, when the event traffic is combined with the regular 4:30 to 6:30 p.m. peak period (week night football game starting times are usually either 6:00 p.m. or 7:00 p.m. Mountain Time). Before a recent Monday night football game, gridlock conditions were observed as far away as 5 mi from the stadium. The Broncos experience a rather high 15 percent transit share to their games, so the driving situation could be a lot worse.

The departure from the event is worse. Data collected from this study indicate that as many as 95 percent of the eventgoers leave the event within 30 min of the end of the event (this time can vary if the special event is a sporting event and one team has a comfortable margin over the other team as the event nears completion).

Automobile Trips

Figure 4 shows the automobile occupancy for weekday and weekend events. Average automobile occupancy for weekend events is some 11.8 percent higher than for weekdays (2.93 versus 2.62). Although this difference may not seem significant, for an event attended by 75,000 fans, assuming 5 percent transit usage, this 11.8 percent difference could account for as many as 3,000 additional automobiles being driven to the event. These 3,000 automobiles contribute over 900 lb of CO and over 90 lb of HC to the air, just within 1 mi of the event site. The automobile occupancy difference is probably caused by the limited ability for leaving work at 5:00 p.m. on a weekday, returning home, forming a carpool, and arriving at the event on time. (Starting times for large evening events are usually 7:30 p.m.)

In many mode choice models nationwide, parking cost is a major determinant in the decision to drive alone, carpool, or take transit. However, as Figure 5 shows, there is no significant difference in average automobile occupancy between sites with parking costs of less than $4.00 and sites with parking costs of $4.00 or more. For events with parking costs of less than $4.00, the average automobile occupancy was 2.78, compared to 2.88 for sites with $4.00 or more parking costs. This difference is probably because of sharing of parking costs among automobile occupancy; the resultant cost per person is a little over $1.00. (The $4.00 parking cost breakpoint was selected to enable equivalent sample sizes.)

Although parking cost does not have any significant impact on automobile occupancy, there is a strong correlation between ticket price and automobile occupancy. Figure 6 shows that for average ticket prices under $10.00, the average automobile occupany is 15.6 percent higher than for ticket prices over $10.00 (2.96 versus 2.56). (The $10.00 breakpoint was used to maintain equivalent sample sizes.) Ticket price is related to demand for and availability of tickets; higher ticket prices usually suggest that demand for the tickets is higher, which many times is accompanied by limits on the number of tickets one can purchase (or that one can afford). Because carpooling to events is usually family or friend oriented, the ability to form large carpools to high-priced events is limited. Figure 7 shows average automobile occupancies by region of the United States. There is no difference in automobile occupancy between Eastern and Midwestern region sites. However, automobile occupancy at Western region sites was significantly lower. This can be attributable to much lower population densities in the West, as indicated in Table 1. Population density has been demonstrated to be a major influence on automobile occupancy; lower densities result in

FIGURE 5 Average automobile occupancy by parking cost category.

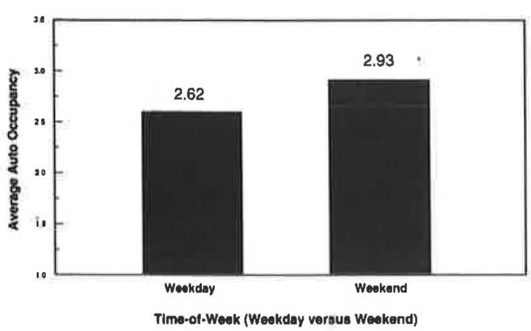

FIGURE 4 Average automobile occupancy for weekday versus weekend events.

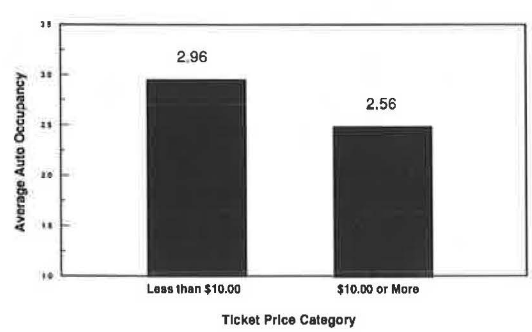

FIGURE 6 Average automobile occupancy by ticket price category.

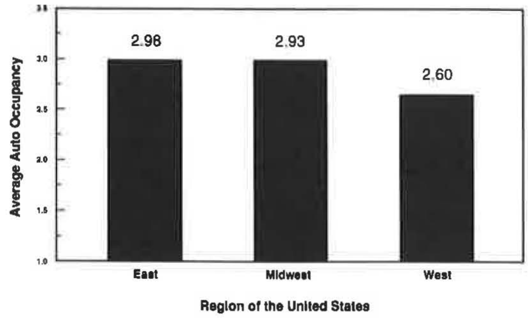

FIGURE 7 Average automobile occupancy by region of the United States.

TABLE 1 POPULATION DENSITY BY REGION, 1986 (*2*)

Region	Density (Pop./Sq. Mi.)
East	1,938
Midwest	931
West	359

longer travel times and distances to form a carpool, thus making carpooling a less attractive mode.

Transit Trips

Transit usage fluctuated widely between sample sites, varying from less than 1 percent to over 20 percent. Several factors seemed to influence the transit mode share. The strongest factor was the availability of public transit to the event site. As Figure 8 shows, sites with public transit available averaged 8.9 percent of total event-goers using transit, whereas the average for charter-only service was around 1 percent. This difference is apparently caused by the familiarity with the public transit operator (one who is visible on a daily basis), as well as the level of service. Also, public transit operators are publicly subsidized, in most cases, allowing them to charge a lower fare than private charter services. Also, places such as Denver, New York, and Kansas City (with the highest transit mode share of the sites sampled) give some preferential treatment to transit, such as close-in parking and exclusive

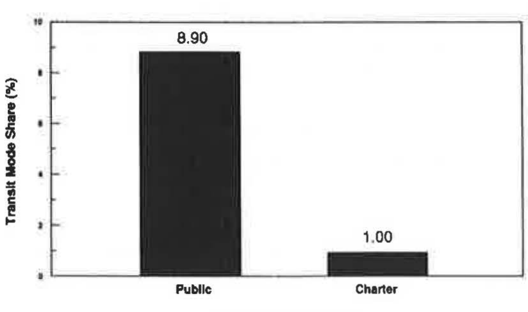

FIGURE 8 Transit mode share by type of transit service.

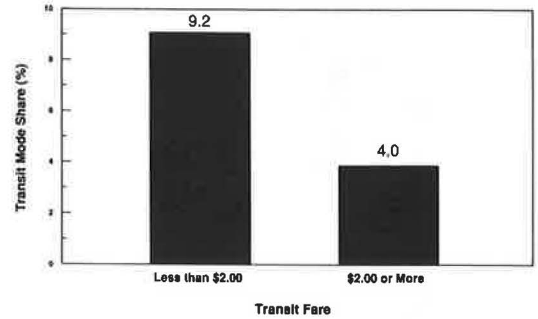

FIGURE 9 Transit mode share by transit fare.

gates for direct access onto entrance and exit roadways at the event site. Figure 9 compares transit fares with transit usage. Also, public transit operators are able to advertise their service to special events, many times on a daily basis (advertisements on board the transit vehicles, brochures or flyers, schedules, etc.).

This difference in transit mode share can have a large impact on air quality. For the example of an event attended by 75,000 spectators, the difference between 8.9 and 1.0 percent mode share can mean an additional 2,000 automobiles being driven to the events site, resulting in an additional 600 lb of CO and an additional 60 lb of HC being emitted into the air.

More people ride transit away from the event than ride it to the event (letter from R. S. Page, Southern California Rapid Transit District). They attributed this phenomenon to people receiving rides to the event (such as friends carpooling from work) and then taking transit to get home. Another possibility is that some people may take a regularly scheduled route to get to the event site, and use the special service to return home. This may be more evident in Denver, where the Denver Regional Transportation District charges users on the trip to the event, and does not charge for the return trip.

The number of attendees from outside the region (defined as the census urbanized area) has an impact on transit share. As Figure 10 shows, as the percentage of attendees from outside the region increases, the transit share declines. This is because of the outsider's unfamiliarity with the local transit system.

The size of the event apparently has no impact on transit usage. For those events with attendance of less than 35,000, the transit share averaged 6.2 percent, whereas for events attended by 35,000 or more, the transit share was 6.8 percent. Statistical tests indicated that there was no significant difference between the transit shares.

RECOMMENDATIONS

After analyzing the data and determining the operational goals of those sponsoring large events, the following recommendations were developed.

When at all possible, regularly scheduled transit service should be provided to the event site.

As shown in Figure 8, those event sites with public, regularly scheduled transit service experienced significantly higher tran-

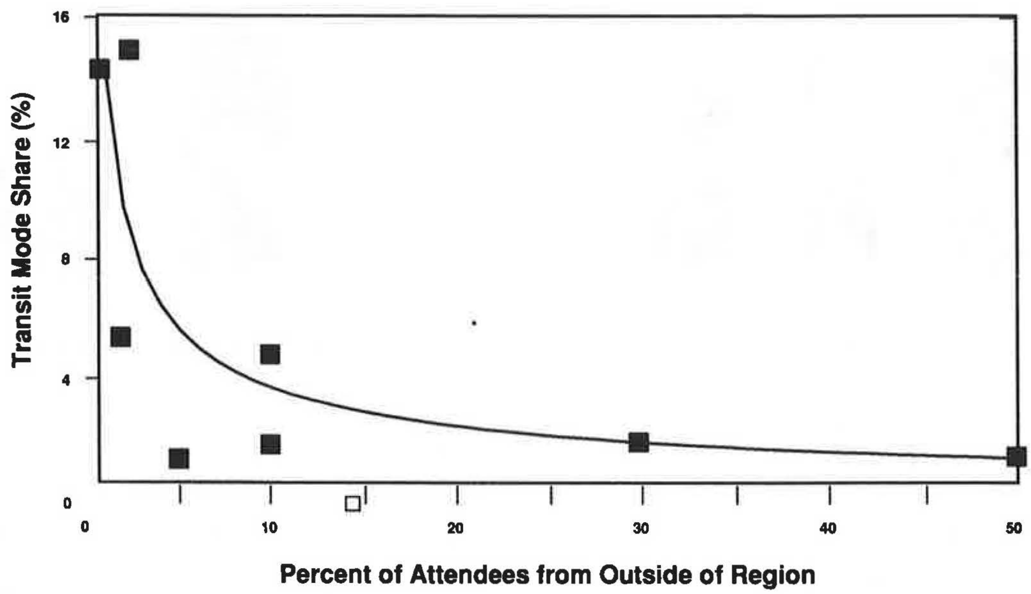

FIGURE 10 Transit share by percent of attendees from outside the region.

sit patronage than those sites served with nonscheduled, charter-type operations. This can be significant, especially in terms of traffic flow and air quality. For the example of an event attended by 75,000 people, if only 5 percent used transit, this would result in some 1,300 fewer automobiles traveling to the site. Using the assumption that the average fan travels 10 mi to the event (this average would be greater for a stadium located in a noncentralized area, such as an outlying suburb), and averages 25 mph on the drive to the event, this would result in a reduction of over 400 lb of CO and over 40 lb of HC for the area within 1 mi of the event site. Regionwide reductions in air pollutants would be higher.

Special events should be held on weekends, or the starting times on weekdays should be delayed at least one-half hour to allow event attendees more time to form carpools or take transit.

Any increase in automobile occupancy or transit share can only be beneficial to air quality. For example, for the event with 75,000 attendees, the difference between weekday and weekend automobile occupany alone results in 3,000 fewer vehicles attending an event of the same size on weekends, compared to weekdays. This means a savings of over 900 lb of CO and over 90 lb of HC in the stadium vicinity alone. Again, region-wide savings would be much higher.

Shuttle services from outlying areas should be provided if there are a large number of event-goers from outside of the region.

As shown in Figure 10, as the percent of event-goers from outside the region increases, their transit share decreases. It is obvious that this is because of a lack of knowledge of the transit service to the event site on the part of those from outside the region. Thus, if a large percentage of event-goers from outside the region are attending an event—such as a sporting event between rival teams in relatively close geographic proximity, a large event that is held a few times per year, or a major stadium concert—to reduce traffic congestion near the event site, a shuttle system should be set up. Obviously, because of the unfamiliarity with the local transit system, shuttle lots should be located on major approaches to the event site (such as Interstate freeways), should be located in outlying areas well removed from the vicinity of the event site, and should be clearly marked on the highway. Park-and-ride lots usually are located along major routes, and would make excellent shuttle lot locations, especially for a centrally located event site.

Transit vehicles should be given priority at events, to make transit usage more attractive.

Many studies of transit systems have indicated that drivers need to be given incentives to shift from automobiles to transit. Transit service alone to an event site cannot be relied on as a major effort to reduce congestion at the event site. Some transit priority measures already in place include close-in parking or transit stations and preferential entrances and exits. These transit priority measures and others, such as bus-only lanes on approaches to the event site, should be considered at all special event sites. Mode split studies performed nationwide have shown that passengers will switch to an alternative mode if that mode can save 1 min of travel time per mile traveled. In the case of a large special event, the time savings will occur in the area within 1 mi of the event site. For an average travel distance of 10 mi, the travel time savings should be approximately 10 min to switch automobile riders to transit. With these transit priority measures in place, it is indeed possible to save 10 min of travel time compared with the automobile mode.

Incentives to arrive early and leave late should be considered to reduce the magnitude of congestion before and after the event.

Figure 2 shows that more than 50 percent of event-goers arrive within 1 hr of the start of the event; other information collected shows that as many as 95 percent of the event-goers leave within 30 min of the end of the event. Incentives should be considered that will allow people to arrive at an event before the peak hour before the start of the event, and to leave the event site well after the end of the event, to reduce the travel "spike" that causes extreme congestion. Incentives to arrive early at events could include pregame (tailgate) parties or preevent festivities. Some sporting events hold Old Timer games or some type of skill contests well in advance of the main event. Incentives to delay departure from the event site could include showing highlights of the event on large video screens, a post-game party (which could be sponsored by a local radio or television station), or coupons for food at nearby restaurants within walking distance of the event facility. (Incentives for the purchase of alcoholic beverages, such as free-drink coupons, should be strongly discouraged.)

CONTINUING STUDY

The data analysis portion of this study should be considered as ongoing, as more information will be included into the inventory in the future. A computer model will be developed and made available for assistance in planning large special events. The model will use as input the following parameters:

- Number of tickets available or expected attendance,
- Type and level of service of transit available,
- Region of the United States where the event is being held,
- Parking costs,
- Transit fares,
- Ticket cost,
- Day of the week of the event, and
- Other parameters affecting mode split that prove statistically significant.

The model will have as output the following:

- Expected average automobile occupancy and number of automobiles,
- Expected transit mode share,
- Estimated air quality impacts,
- Recommendations for traffic congestion alleviation, and
- Other output parameters determined to be of use in planning major events.

If resources become available, work on model calibration and validation could begin in 1991.

SUGGESTIONS FOR FURTHER STUDY

During the data analysis process, several data anomalies appeared that suggested that further study was necessary. These were the following:

- A general decrease in automobile occupancy as the attendance increases, as shown in Figure 11.
- The West experiences the highest transit mode share to large special events, as shown in Figure 12.
- The transit share for event sites with automobile parking costs of less than $4.00 is more than double the transit share at event sites with parking costs of $4.00 or more. This is contrary to mode split studies performed for regional transportation planning purposes, however, there may be some correlation between the indifference in automobile occupancy relating to parking costs.
- The transit mode share on weekdays is significantly higher than on weekends. This may be caused by improved transit service levels during the week (i.e., more frequent service).
- There is general decline in transit mode share as the automobile occupancy increases. This decline may indicate that

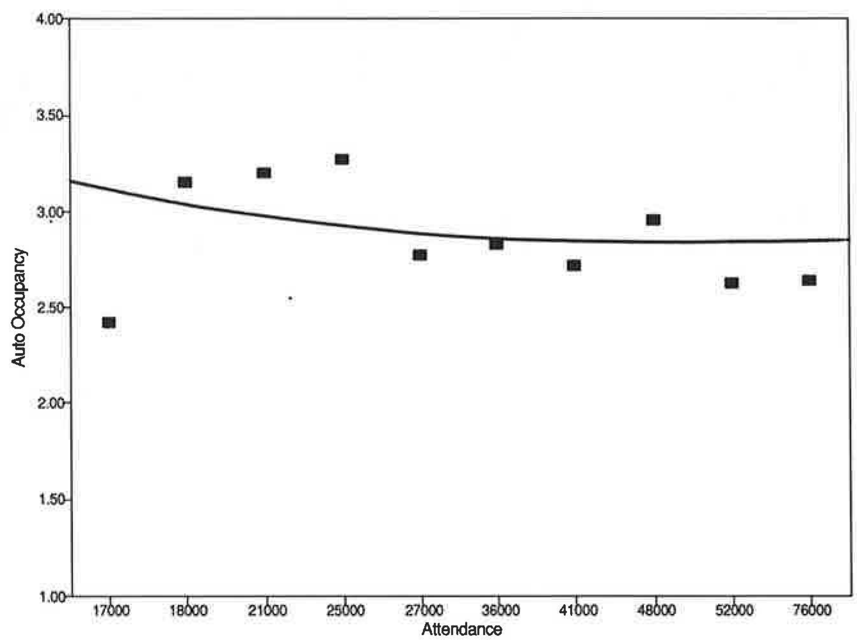

FIGURE 11 Automobile occupancy by attendance.

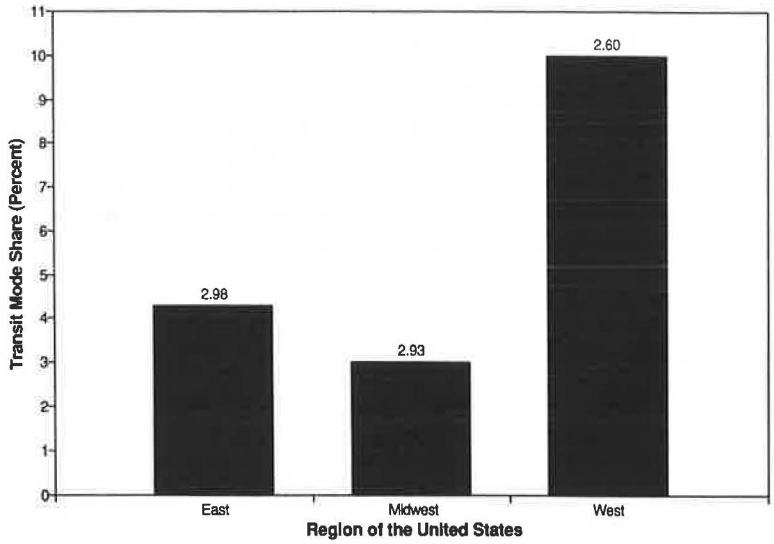

FIGURE 12 Transit mode share by region of the United States.

there is a trade-off between transit riders and automobile passengers.

- There may be some correlation between large special events and air quality monitoring stations reporting air pollution violations. Data collected from the Colorado Air Pollution Control Division and a report from the City and County of Denver (*3*) indicate some correlation between Denver's annual Parade of Lights and high pollution days.

It is also recommended that the study be continued to include more sample data. Because the data included in this report were grouped for testing, in most instances regional travel behavior differences may not appear in these results. Also, because of the relatively small number of samples taken, it is suggested tht continued data collection is needed. If sufficient resources become available, it is also suggested that the above anomalies be studied further. It is possible that a more intensive data collection effort, if not able to explain these anomalies, would serve to reduce or eliminate them.

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