Day-of-Week and Part-of-Month Variation in Bus Ridership: Empirical Results

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ABSTRACT

Results from a study of bus ridership during a 2-year period on the Central Ohio Transit Authority indicate that ridership depends systematically and strongly on the day of the work week and on the part of the month. Ridership tended to decrease from Monday through Friday and was higher at the beginning than at the end of each month. Possible causes of these effects are presented and their implications for transit planning are discussed.

The number of trips made in an urban area varies in time. More work trips occur during certain times of the day than during others, and fewer trips occur on weekends. Sickness may cancel different numbers of individual work trips on different days. Shopping and recreational trips from the same origin to the same destination may not be made every day; when they are made, they may be made at different times of the day. Vacation trips are more prevalent during certain seasons than during others. When variability in modal choice decisions is added to this variability in trip-generating characteristics, it stands to reason that the number of trips made using transit on a certain route will vary by season, by day, and by time of day.

Recognizing and understanding this temporal variability in transit patronage is important in transit planning for several reasons. Headways can be increased to balance decreasing demand, as is typically done during off-peak, weekend, and holiday periods. Medium-range scheduling and routing decisions are based on estimates of current and past patronage. These estimates are derived from samples taken during specific time periods (1,2). If the estimates are to be useful for other or longer time periods, the characteristics of the periods during which the samples were taken must be considered (3). Similarly, the results of a sample on socioeconomic characteristics of the riders could be biased if the sample were conducted at times when certain groups were over- or underrepresented.

A better understanding of the reasons for temporal variability in transit patronage could also permit a better marketing of transit services. Scheduling and routing decisions would be part of this marketing package. Temporal pricing might be used to induce ridership during price-elastic periods and to increase revenues during price-inelastic periods (4). Service may be improved in those attributes that cause individuals who would otherwise use transit to switch modes or to forsake trips at certain times.

It is widely accepted that transit ridership depends systematically on the time of the day and on whether the day is a workday. It is also suspected that systematic variability in transit patronage occurs on different weekdays (2,3). However, no formal documentation of this suspected day-of-the-week effect appears to exist. Personal discussions with transit operators have revealed a suspicion that ridership is greater at the beginning than at the end of the month. But again, the authors know of no empirical evidence documenting this part-of-the-month effect.

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Presented in this paper is empirical evidence that indicates that bus ridership on the Central Ohio Transit Authority (COTA) system depends on the day of the week and on the part of the month. To the authors' knowledge, it represents the first formal documentation of such empirical evidence. The difference between two days of the same work week is only between 3 and 4 percent on the average. Yet the difference occurs so systematically that a clear trend is denoted: as the week progresses, ridership decreases. The difference between the beginning and end of the month is much larger, more than 10 percent on the average. This comparison also indicates a strong trend: ridership is higher at the beginning of the month than at the end.

In the next section, the data used in the study and the methods needed to investigate day-of-the-week and part-of-the-month effects are described. In Section 3, the results indicating these effects are presented. In the final section, possible causes of the effects are speculated on and their practical implications for transit planning are mentioned.

STUDY DESIGN

Objective and Definitions

The objective of the study was to investigate variability in transit ridership as a function of the day of the week and part of the month. If such variability exists, it should be considered when designing sampling and marketing strategies. It would also influence the way in which transit agencies estimate daily patronage from more aggregate data such as monthly passes. If such variability does not exist, the current work on developing sampling strategies to account for it would be unwarranted. Also, it is argued that the existence of a day-of-the-week effect would influence the analytical methods necessary to investigate a part-of-the-month effect and vice versa.

Day-of-the-week effect means a cyclic pattern in transit patronage that is correlated with the work week. Specifically, this effect will be said to exist if the level of transit patronage on a given day of the work week--Monday, for example--differs systematically (across weeks) from the level of transit patronage on the other days of the same work week.

Part-of-the-month effect means a cyclic pattern in transit patronage that is correlated with the calendar month. Specifically, this effect will be said to exist if, when the month is divided into a given number of periods, which do not necessarily exhaust the month but which are similarly defined from one month to the next, the level of transit patronage during one of these periods differs systematically (across months) from the level of transit patronage during the other periods of the same month.

Data

To investigate these effects, systemwide bus revenue data furnished by COTA were used. The data covered a 2-year period, from January 1, 1982, through December 31, 1983. The period from November 22 to December 10, 1982, was excluded because of a drivers' strike.

COTA maintains daily systemwide records for a number of patronage statistics. COTA estimates daily patronage by summing the following:

1. An estimate of the number of daily cash (fare box) passengers derived from fare box revenue by using an average fare procedure (2);
2. The number of passengers buying single-use tickets;
3. An estimate of daily usage by monthly pass purchasers obtained from a linear formula by using assumed parameters (which do not currently account for day-of-the-week or part-of-the-month variation); and
4. An estimate of the number of nonrevenue-generating passengers obtained from the number of revenue-generating passengers by using a fixed percentage.

In this procedure, then, the only data obtained directly for a given day are the fare box revenue and the number of tickets sold.

COTA also records daily ticket revenue. These data are obtained without assumption by multiplying the price of each ticket category by the number of tickets sold daily in each category. By using only direct empirical data--data that are not derived by using assumed parameters--the most information on daily variation in patronage is obtained by summing the daily fare box (cash) and ticket revenues. These are the data that were used for analysis.

Representative Statistics

To investigate variability according to the day of the week, one could compare the averages, taken over the 2-year period, of the cash and ticket revenue for each weekday. (The authors shall not be concerned with weekends and holidays in this study because the decreased patronage on these days is well accepted and because there are as well significant differences in the service supplied.) These averages shall be denoted $\bar{X}$, where X = M, T, W, Th, F, respectively, representing the consecutive days of the work week.

It would be surprising if the averages for two different days of the week were identical. However, to determine if they were markedly different, the variances of the distributions of the revenue data for individual weekdays, Xi, during the 2-year period about the sample mean, $\bar{X}$, would have to be considered. However for data such as those of the authors, serial correlation might inflate the variances. Specifically, it would be possible that for all weeks, i, the revenue data for a given day of the week, Xi (e.g., Monday), would be higher than those for a different day, Yi (e.g., Tuesday). This would lead not only to $\bar{X} > \bar{Y}$, but to Xi > Yi for all i, which is exactly the day-of-the-week effect. Yet if revenue figures for various weeks differed by enough--perhaps because of a seasonal effect (5) or part-of-the-month effect--the variances of the distributions of the Xi's and Yi's might be great enough to make the differences between the means, $\bar{X} - \bar{Y}$, appear to be insignificant. Indeed, a Durbin-Watsen (6) test indicated that this type of serial correlation did exist in the authors' data set (5).

To reduce this problem, the authors analyzed the difference in the cash and ticket revenues between pairs of weekdays in a given week. That is, they defined

$$DXYi = Xi - Yi \quad (1)$$

where Xi and Yi are the cash and ticket revenues for two different days in a given week, i. To avoid double counting, this difference, DXY, was taken for all combinations of weekdays such that X occurred before Y in the week. For example, when X represented Monday, DXY was formed for Y representing Tuesday, Wednesday, Thursday, and Friday; when X represented Thursday, DXY was only formed for Y representing Friday. This also ensured that a positive (negative) value of DXY indicated that the revenue data of the earlier day of the week was higher (lower) than that of the later day of the week.

A part-of-the-month effect would influence the value of these DXYi's where X and Y represented 2 days during the same week but during different months. Specifically, if the first part of the month exhibited patronage significantly higher or lower than that of the last part of the month, the difference between Xi and Yi would be influenced when Xi was the final X in a month and Yi was the first Y in the following month. To avoid this problem, any DXYi's where Xi and Yi were in different months were eliminated from consideration. A Durbin-Watsen test indicated that the authors' final set of DXYi's did not exhibit serial correlation.

To compare the patronage differences as a function of the part of the month, the authors formed the average of the cash and ticket revenues over the first 5 weekdays of each month and the average of the cash and ticket revenues over the last 5 weekdays of each month. That is, the authors determined

$$Bj = (Mbj + Tbj + Wbj + Thbj + Fbj)/5 \quad (2)$$

$$Ej = (Mej + Tej + Wej + Thej + Fej)/5 \quad (3)$$

where Mbj, Tbj, Wbj, Thbj, Fbj represent, respectively, the cash and ticket revenues for the first (beginning) Monday through Friday of month j; and Mej, Tej, Wej, Thej, Fej represent, respectively, the cash and ticket revenues for the last (ending), Monday through Friday of month j.

By including an observation for each weekday, the impact of the day-of-the-week effect on the statistics representing the beginnings and ends of each month was reduced. If a holiday occurred on any of the first or last 5 weekdays of the month, the holiday was eliminated from the average. The results were so strong for the part-of-the-month effect that it did not appear necessary to control for a bias related to day-of-the-week effect induced when eliminating certain days (e.g., Monday) more often than others.

Variation in patronage among different months would increase the variance in the distributions of the Bj's and Ej's. Therefore, the difference between the statistics representing patronage at the beginning and end of month j (DBEj) was taken:

$$DBEj = Bj - Ej \quad (4)$$

RESULTS

Day-of-the-Week Effect

In Table 1, the average, taken over the 2-year period, of the fare box and ticket revenues for each weekday is presented. Also presented are the standard deviations of the distributions of the individual days. The mean revenue figure decreases from Monday through Friday. However, given the size of the standard deviations, one could not readily conclude that there is a strong day-of-the-week effect.

TABLE 1 Average and Standard Deviation of Revenue on Individual Weekdays ($)

Weekday	Average	Standard Deviation
Monday	21,500	1,680
Tuesday	21,000	1,570
Wednesday	20,700	1,280
Thursday	20,700	1,470
Friday	20,500	1,480
All weekdays	20,900	1,530

In Figure 1 the distributions for all the paired differences, the DXY's, are shown. The average difference, D, may not be a large percentage of the average revenue figure of $20,900 given in Table 1. (It ranges from slightly more than 1 percent to more than 7 percent.) Yet all of the distributions are biased toward positive values, indicating that the ridership on the earlier day of the week is systematically greater than that on the later day. Note also that the distributions that are shifted the farthest to the right--for example, those of the differences between Monday and Friday, Monday and Thursday, or Tuesday and Friday--are those representing weekdays that are most separated in the week. The impression is that ridership (at least cash and ticket revenue) tends to decrease as the week progresses.

The sample means and standard deviations of these distributions are summarized in Table 2. The numbers

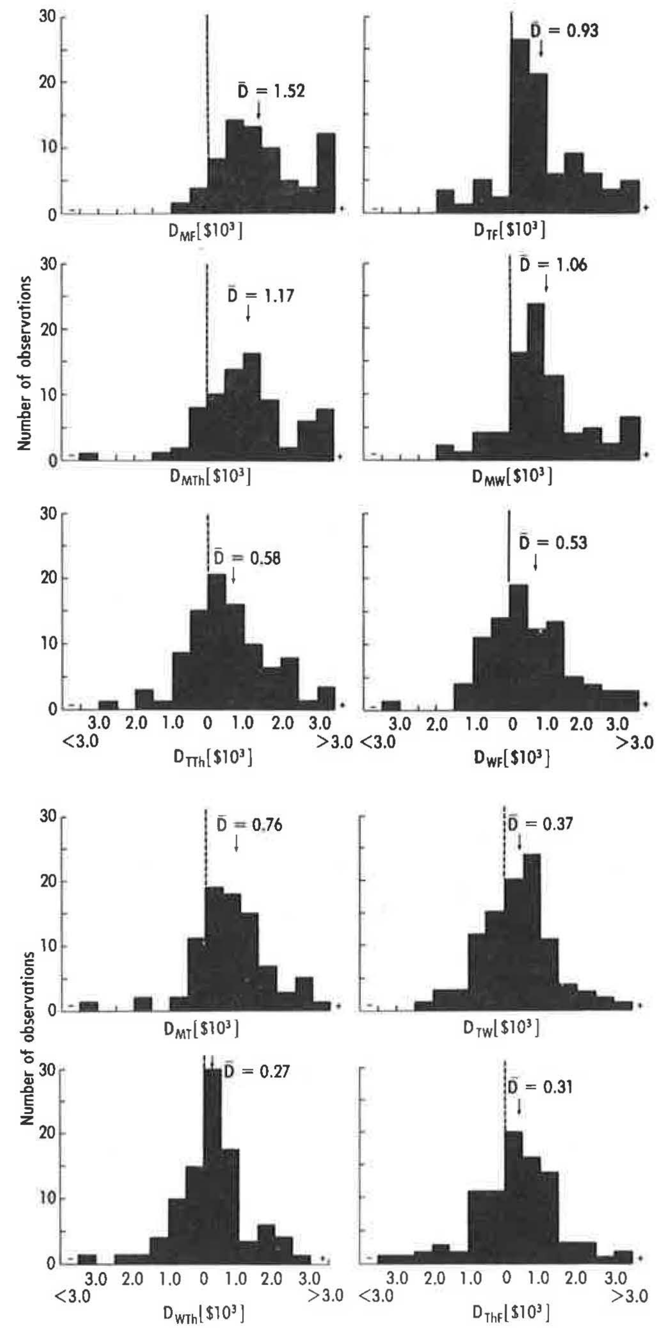

FIGURE 1 Distribution of revenue differences, D, between pairs of weekdays, X and Y, during same week and same month.

TABLE 2 Statistics of Revenue Differences Between Pairs of Weekdays

Days Compared (XY)	No. of Days of Separation in Week	Average Difference DXY ($)	Standard Deviations of Differences ($)	No. of Observations	t-statistic
Monday-Friday	4	1,520	1,400	71	9.15
Monday-Thursday	3	1,170	1,280	77	8.02
Tuesday-Friday	3	930	1,310	87	6.62
Monday-Wednesday	2	1,060	1,230	83	7.85
Tuesday-Thursday	2	580	1,170	93	4.78
Wednesday-Friday	2	530	1,220	89	4.10
Monday-Tuesday	1	760	1,060	84	6.57
Tuesday-Wednesday	1	370	1,040	99	3.54
Wednesday-Thursday	1	270	980	95	2.69
Thursday-Friday	1	310	1,220	92	2.44

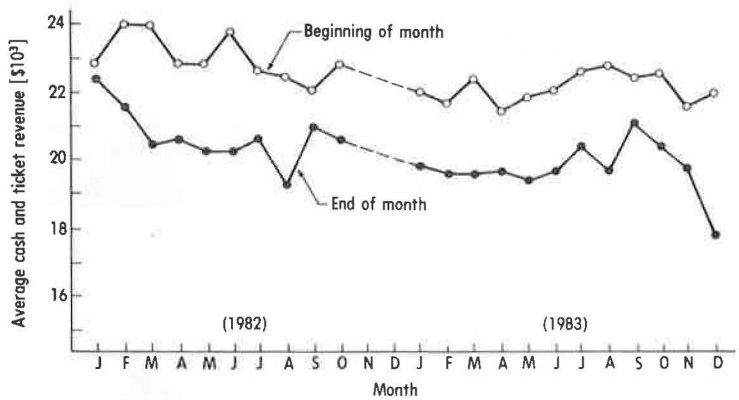

FIGURE 2 Revenue data for beginning and end of months.

of observations for each paired difference are also presented. The number of observations differs because the authors eliminated any pair involving a holiday and those pairs for which the 2 days constituting the pair were in different months.

A t-test on the paired differences implies that the hypothesis that the revenue data for any 2 different weekdays were generated from the same distribution should be rejected at the 0.01 level. (The calculated t-statistics are presented in Table 2.) It should be noted here that any seasonal variation (5) in ridership would tend to increase the variance in the paired differences, thereby making it more difficult to reject the hypothesis of a difference according to weekdays. Thus it can be observed that even a conservative test indicates significant differences in ridership among different weekdays during the same week.

Part-of-the-Month Effect

In Figure 2, the time series of the revenue statistics for the beginning and end of each month are shown. (Data for the months of November and December 1982 are not used because of the influence of the drivers' strike.) The revenue at the beginning of the month is always higher than that at the end of the month. The graph in Figure 3 reinforces this image by portraying the distribution of the differences between the statistics representing the beginning and end of each month. The average difference of $2,350 is more than 11 percent of the average weekday total of $20,900 given in Table 1. The calculated t-statistic for this distribution is 12.55, which makes it possible to reject at the 0.0001 level the hypothesis that the revenue data at the beginning of each month and the data at the end of each month can be modeled as coming from the same distribution.

It should be noted that such a strong part-of-the-month effect could overwhelm the day-of-the-week effect observed previously. In Figure 4, a plot of the distribution of the differences between the revenues of all weekdays occurring during the same week yet during different months is shown. Once again, this difference was formed such that the revenue of the day that occurs later in the week (but earlier in its month) is subtracted from that which occurs earlier in the week (but later in its month). Unlike the distributions in Figure 1, this distribution has a strikingly negative bias, indicating that the part-of-the-month effect is overshadowing the day-of-the-week effect. (The only two positive values occurred for differences between

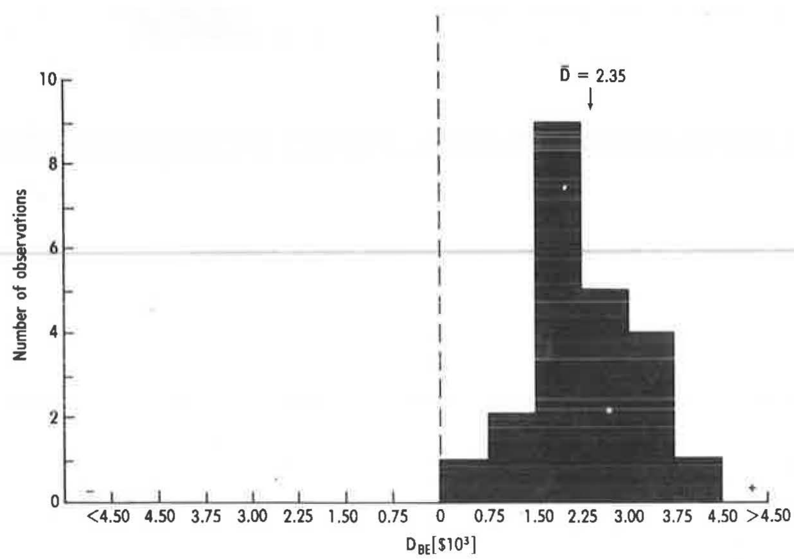

FIGURE 3 Distribution of revenue differences, D, between beginning, B, and end, E, of months.

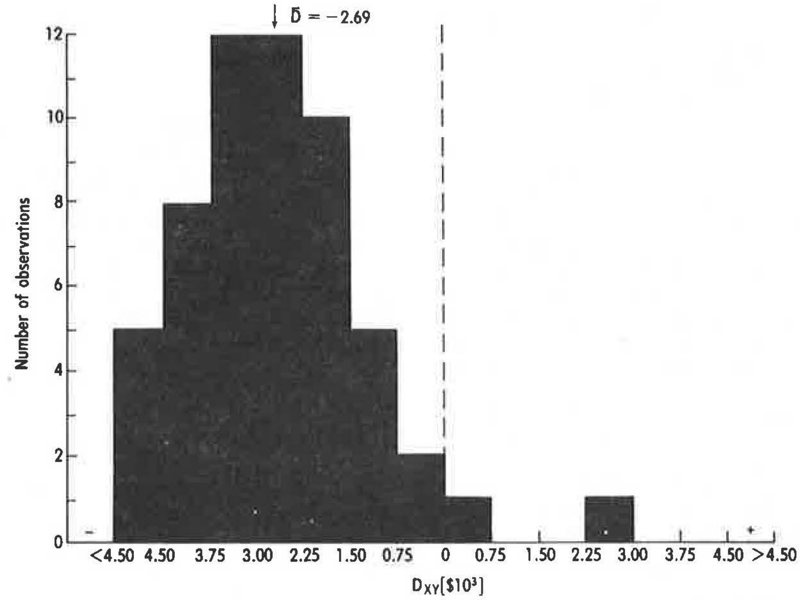

FIGURE 4 Distribution of revenue differences, D, between pairs of weekdays, X and Y, during same week but different months.

revenues for Monday-Friday pairs.) The average difference is almost 13 percent of the average weekday total given in Table 1.

DISCUSSION OF POSSIBLE CAUSES OF TEMPORAL VARIABILITY OF BUS RIDERSHIP

No formal investigation of reasons for trip making was conducted. Nevertheless, it is tempting to speculate on the possible causes of the effects observed.

A possible reason for the part-of-the-month effect is the difference in disposable income between the beginning and end of a month, particularly among certain groups of riders. COTA schedulers remarked that they perceived ridership to be higher in the beginning of the month and believed that this increase was due to the distribution of entitlement checks at the beginning of each month; it was this remark that led the authors to investigate a part-of-the-month effect. Interestingly, a casual conversation with a local taxi driver revealed a similar perception: the driver said he did much better business at the beginning than at the end of the month because he carried more welfare recipients at the beginning of the month when they had just received their checks.

A technical reason contributing to the part-of-the-month effect could be related to the use of revenue data to indicate ridership. If many pass holders waited until the second week, or even late in the first week, of the month to purchase their passes, the cash and ticket revenue at the beginning of the month would be increased relative to that at the end of the month. However, the size of the difference between the beginning and end of the month is so large that it is unlikely that this alone could explain the results.

A decrease in the number of trips generated might also contribute to the day-of-the-week effect. If decreased disposable income does contribute to the decrease in trip making observed in the part-of-the-month effect, it could cause a decrease in trip making on a daily basis. That is, if disposable income continuously decreases from the beginning of a month to the end of a month for those making discretionary trips, it would also decrease continuously from the beginning to the end of each week, provided the entire week is contained in the same month.

It is also possible that personal business trips, such as trips to the bank or post office, are stored up on Saturday afternoon and Sunday, thereby yielding a higher potential for generating this type of trip at the beginning of the week. Some of these trips, the inventory of which is dissipated as the week progresses, will be made by transit. Finally, fewer work trips may be generated at the end of the week because of long weekends. Casual observation indicates that people are more likely to make long weekends by taking off Friday from work than Monday.

Diversion of trips from transit to automobile may also explain some of the day-of-the-week effect. The hypothesis here is that those individuals who frequently use transit for work trips, yet have an automobile available to them, will have a higher probability of choosing to use the automobile when their after-work activities deviate from the traditional pattern. After-work social activities appear to be more prevalent at the end of the week. Many stores remain open later at the end of the week. Individuals tend to leave work earlier on Fridays than on other days of the week. Individuals who might otherwise use transit to go to and from work may need an automobile to perform these after-work activities or may be unfamiliar with transit service other than that which they use for their routine commute.

Implications of Results

It is emphasized that the reasons just given for the observed day-of-the-week and part-of-the-month effects are purely speculative; no formal investigation of the causes was conducted. However, whatever the reasons for the effects, they have important implications for transit planners. If the trends in variability were known, sampling resources could be used more efficiently by factoring in the variability rather than avoiding days that have been proposed to be variable--Mondays and Fridays, for example.

Likewise, sampling techniques for passenger counts, interviews, and surveys must be designed with this variability in mind. The authors' results cannot be interpreted to imply that ridership is always higher on Monday than on Tuesday, which is higher than on Wednesday, and so on. Indeed, several of the differences shown in Figure 1 are negative. However, the results do imply that unless a specific transit agency has found reasons to believe otherwise, it should expect systematic variability to exist, depending on the day of the week and on the part of the month. Not accounting for this variability in sampling strategy can lead to biased samples, which may in turn lead to misguided policy decisions, particularly if much of the variation occurs on low-volume routes the continued existence of which depends on sample results.

Agencies that estimate daily ridership based on monthly statistics may also wish to consider the variability witnessed here. It is currently assumed by COTA that the same fraction of monthly pass customers uses the transit services on any weekday and at any time of the month. Empirical evidence implies that this may not be the case.

Large fixed-schedule systems will probably not adjust daily or weekly schedules to account for variability. However, demand-responsive systems may wish to acknowledge such variability when planning the number of operators needed, or when determining a fleet size that balances overcapacity and under-capacity. This proposal would be contingent on the existence of such variability in the ridership for those forms of transit service. Given that the authors know of no study contradicting their results for any transit mode, they are led to believe that it is possible that systematic daily variability occurs in demand-responsive transit as well.

Additional Work

The results of this study imply a broad research agenda. It would be interesting to know whether the daily trend observed in this study--that is, a decrease in transit patronage as the week progresses--is specific to the COTA system or if it is common to a number of urban systems with similar characteristics. It would be useful to be able to identify these characteristics. The transferability of the results could be investigated both through empirical studies of other transit agencies and through behavioral studies designed to identify the causes of the effects observed.

Furthermore, this study was conducted on a systemwide basis with data aggregated over the period of a day. Ridership surveys and counts are conducted at the route level and at a specific time. It would be useful to conduct a similar study on specific routes. This type of investigation would indicate whether all routes exhibit the same type of variability, and if not, the characteristics that would allow the type of variability to be exhibited on a specific route to be predicted. Conducting investigations at different times of the day would be useful in determining whether the variability occurs during both peak and off-peak periods. Because variation among disaggregate components is generally greater than that of the whole, larger variations than those noted in this paper would be expected to occur on individual routes and during specific time periods.

Time-of-day and seasonal effects in transit patronage are well accepted and easily explained. Evidence now exists that factors associated with the day of the week and the part of the month are also important.

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