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Foreword

The seventeen papers in this Record, presented at the 1991 Annual Meeting of the Transportation Research Board, have been grouped into two parts: Part I, Transit Management and Marketing; and Part II, Transit Planning. These papers provide a cross section of recent transit research that has been undertaken on these topics.

The first three papers in Part I, two papers by Henderson et al. and one by Bregman and Hynes, describe studies performed to gain a better understanding of transit performance and operations. Service regularity for short headway operations, on-time performance (which is the most common service reliability measure used by transit managers), and comments and recommendations made by consumers at neighborhood transit workshops were evaluated. The papers include descriptions on how these indicators can be applied to improve transit operations.

Barnum and Gleason review concepts from probability theory and drug-testing applicable to testing for multiple drugs use, apply these concepts to laboratory proficiency and transportation drug-use data, and estimate the accuracy levels that could occur in transit agency drug testing programs.

In the next two papers, Ambruso describes transit marketing programs to increase transit use in Portland, Oregon. Ambruso first reports on a marketing campaign to promote the use of a new park-and-ride lot and the express bus serving the lot. In the second paper she reports on a marketing promotion that targets new residents to influence their riding behavior before they make long-lasting commute pattern decisions. Andrle et al., in the last paper in Part I, discuss the lessons learned from a distance-based fare transit marketing demonstration.

The papers in Part II cover a wide range of topics or transit planning. Mitric traces transit developments in Morocco during the 1980s. Black provides a dissenting view of the privatization movement that has received mostly favorable reviews. McLeod et al. describe a multiple regression model that was used to analyze transit ridership in Honolulu.

Taylor, in his paper on unjust equity, examines California's Transportation Development Act and its allocation formulas. He finds that the per capita formulas used in the allocation strongly favor lightly patronized suburban transit service over central city service. The next two papers concern the demand side of transit planning. Khasnabis et al. present the results of a private provider survey and demand-based market analysis used in the Detroit metropolitan area. Sheskin reports on a survey of behavioral intent and actual behavior in transit use conducted for Metrorail in Miami.

It is generally recognized that it is immensely difficult for transit to serve suburban areas as they are currently being developed. It appears that this will continue, as Beimborn et al. found in their analysis of an international city design competition. Of the more than 250 entries from some 40 countries, less than half explicitly used public transit and only 12 percent were judged to have used it well. Moriarty et al. summarize the planning and innovative transportation program for the University of Illinois at Urbana-Champaign. The system integrates new campus bus routes with the existing regular routes of the local transit district.

In a combined time-series and cross-sectional regression model to forecast transit ridership, Ferguson reports that significant serial and seasonal fluctuations were found in the transit service in Orange County, California, between 1973 and 1989. It was found, for example, that fares and gasoline prices had no significant effect on ridership, partly because more than 70 percent of the travelers are captive riders who have no car available to them for commuting or other travel purposes.

In the final paper, Fahey and Gray describe the emergency ferry service that was put into place in the San Francisco Bay area immediately following the Loma Prieta earthquake in October 1989. Also discussed is the development of a long-range plan for permanent Bay Area ferry service.

Regularity Indices for Evaluating Transit Performance

GARY HENDERSON, PHILIP KWONG, AND HEBA ADKINS

Service regularity measures for high-frequency transit are nonexistent at many transit operating agencies. Measures being used or those developed in theory are usually unsatisfactory for one of two reasons: (a) they do not control for the size of headways and therefore cannot be used to compare one route with another, or (b) they are not expressed on a normalized scale (i.e., bounded by 0 and 1). Two measures address these problems: the headway regularity index and passenger wait index. These indices are analyzed and compared both by means of mathematical analysis of data from simulations and by data from actual observation of bus routes in New York City.

This research originated with the Metropolitan Transportation Authority (MTA) inspector general's examination of the performance measurement systems used by the New York City Transit Authority (NYCTA). At the time this work was done, the NYCTA had no measure of the evenness of bus headways that was applied on a routine basis to all bus service. The NYCTA did calculate the percentage of excessive headways for bus routes when schedule revisions were made. By excessive headway, the NYCTA meant that the headway was more than 4 min greater than scheduled (*1*). This measure was used to demonstrate the effectiveness of the schedule revision program. The problem with this approach was that the 4-min standard had a different meaning when applied to service running every 2 min than it had for service running at 8- or 20-min intervals. Because the measure was used only for bus routes when schedule revisions were made, it was not being used to test whether other operational initiatives were successful.

The best previous regularity measure used by the NYCTA for subways was rush hour throughput—the percentage of trains scheduled that actually passed the observation point during a 1-hr interval. In practice, this measure became a measure of service volume and described little about the regularity of the intervals during the given hour.

A variety of measurement techniques are available to evaluate the performance of frequency transit services. These techniques include calculating the percentage of excessive headways (*1*), average wait (*2,3*), coefficient of variation for headways (*4*), and excess waiting time and standardized excess waiting time (*5*). All these techniques are useful analytical tools, but they have two major drawbacks.

Some of the measures depend on the average scheduled headway, that is, they have larger values for routes with larger headways. Therefore, a comparison of routes with different scheduled headways is not useful. Other measures are mathematically independent of the average headway (e.g., London Transit's standardized excess wait), or they at least control for headway variation (e.g., the headway coefficient of variation). These indicators allow comparison of routes, but their mathematical expression makes them difficult to evaluate. They are not represented on a normalized scale, so there is no set upper bound. Such measures are especially difficult for consumers to interpret, because it is difficult to tell how far the service diverges from the optimum. For example, the headway coefficient of variation is generally between 0 and 1 for bus routes, but at times it can exceed 1.

Two measures are examined for evaluating transit services—the headway regularity index (R) and the passenger wait index (W). Both indices control for the average headway and both are expressed on a normalized scale from 0 to 1.0. For perfect regularity, when all headways are equal, both measures equal 1.0. When all buses arrive bunched together, the value of both indices is 0. To simplify application of Gini's ratio to transit services, the headway regularity index is defined as one minus Gini's ratio (*6,7*). The passenger wait index is the ratio of the actual average wait to the minimum average wait (which occurs for perfect regularity).

These measures were examined by means of Monte Carlo simulations and other mathematical analysis. Headway data were generated randomly under a series of conditions to test how different configurations of headways produced different values for the indices and to show how these values compared with each other and with the coefficient of variation. In addition, the properties of the indicators were analyzed by examining their instantaneous rates of change.

The indices were explored also by applying them to empirical data from three case studies conducted by the inspector general's office for the MTA (*8–10*). The midday performances of the following selected New York City bus routes were examined: the Bronx Bx28, Bx30, Bx41, and Bx55; Brooklyn B35 and B46; and Manhattan M2, M3, M4, M7, M11, M16, Q32, M34, and M79. These routes were observed on randomly selected workdays between March and November 1989. The times of bus arrivals were recorded to the nearest half-minute.

HEADWAY REGULARITY INDEX

Gini's ratio is used by economists and sociologists to measure the degree of income inequality within groups of people (*6*). The task for transportation is somewhat different, but the technique is analogous. Inequalities in actual headways for bus routes are sought. To evaluate service quality and op-

New York State Office of the Inspector General, Metropolitan Transportation Authority, 100 Park Avenue, 14th Floor, New York, N.Y. 10017.

erational efficiency, the headway regularity index calculated for a given route can be compared with 1.0, the value of the index for perfectly regular service. Only actual headways are recommended for this analysis because adjusting the measure to compensate for scheduled unequal headways would put the results at odds with what passengers waiting at a particular location would experience.

The headway regularity index controls for the average actual headway. Just as the political economist can compare one nation's distribution of wealth with another's, without reference to which has the higher standard of living, headway regularity for the Bx41 bus route can be compared with that for the Bx30, though the two routes have quite different average headways.

Although a high value (near 1.0) for Gini's ratio indicates great income inequality, a high value (near 1.0) for R indicates regular service. A low value for R indicates irregular service and bus bunching.

Several properties of Gini's ratio mentioned in the *Encyclopedia of Statistical Science* (6) make the regularity index an attractive measure for evaluating transit performance.

1. Transfers. Supervisory actions, such as holding back buses or turning them short, if successful, will redistribute headways and increase the value of the index. This process is useful in testing the effectiveness of road supervision.
2. Scale Independence. Proportional addition or subtraction to all headways leaves the index unchanged. This means that schedule changes that increase or decrease the scheduled headway will not affect the index, except insofar as the changes improve or worsen service regularity. Scale independence also provides the justification for mathematical techniques for aggregating time periods with different scheduled headways, e.g., combining peak and off-peak service in a composite measure.
3. Normalization. The scale ranges from 0 to 1. All routes are calibrated to the same scale, making comparison possible. The upper limit provides a sense of how the given route compares with optimum service regularity.
4. Operationality. Because the index is straightforward, unambiguous, and objective, different researchers with potentially different subjective interests will still produce the same measure of regularity.

An illustration of the regularity index is shown in Figure 1. The horizontal axis is the cumulative proportion of buses (headways), ordered from the smallest to the largest headway. The vertical axis represents the cumulative proportion of the total headway minutes of the individual buses as they are arrayed on the x-axis. Expressing these axes as proportions, instead of the number of minutes or the count of buses, controls for headway size.

The diagonal line is the function that describes perfectly regular service, i.e., each bus adds an equal percentage of headway minutes to the total headway. The curve below that, known as the Lorenz curve (*11,12*), is the function that describes actual service. The black area represents the difference between actual service and perfectly regular service. The regularity index is the ratio of the shaded area to the area of the entire triangle. Gini's ratio is the ratio of the black area to the entire triangle.

In this diagram, the curve describing actual headway regularity indicates that the smallest 20 percent of the headways (buses) account for less than 5 percent of the total headway. The first 60 percent of the buses, ranked from the smallest to largest headway, accounts for about 40 percent of the total headway. The R value for the data used to make this diagram is 0.70. (The shaded area equals 70 percent of the triangle.)

The classical formula for Gini's ratio (*4*) is given in terms of an integral:

$$g = 1 - 2 \int LdF \quad (1)$$

The formula for the regularity index is

$$R = 2 \int LdF = 1 - g \quad (2)$$

where $\int LdF$ indicates the area under the curve for the actual observations, measured by calculating the definite integral. In the formula, L represents the function (Lorenz curve) that

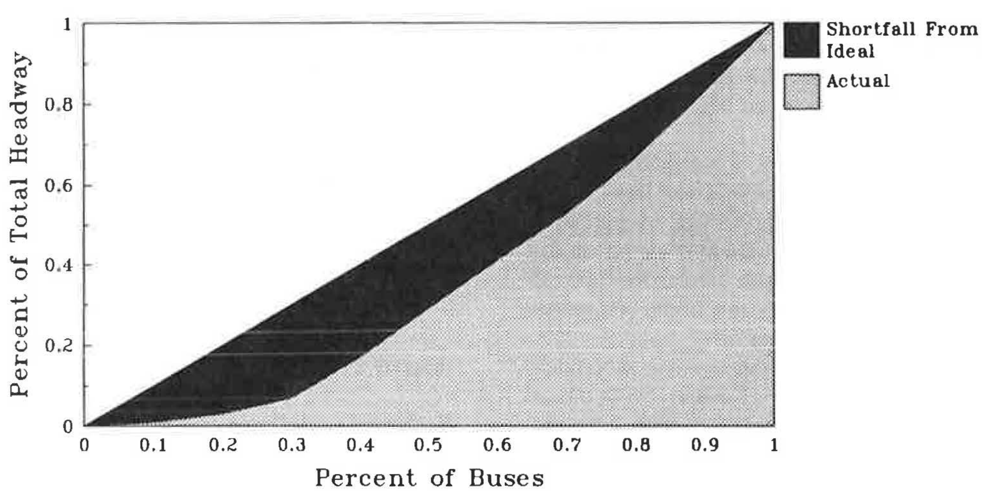

FIGURE 1 Calculation method for the regularity index. (Source: N.Y. State Office of the Inspector General for the MTA.)

describes the observed headways, and F represents the cumulative distribution function for the buses (ordered from smallest to largest headway), i.e., the x-axis in Figure 1.

However, the integral representation is not useful for calculating the measure with real data sets. Therefore, the following shortcut formula for R was developed:

$$R = 1 - \frac{2 \sum (h_r - H)r}{n^2 H} \tag{3}$$

where

- h_r = series of headways;
- r = 1, . . . n, the rank of the headways from smallest to largest; and
- H = mean headway.

This formula is useful for calculating the regularity index on a standard spreadsheet computer program. In fact, attempts to array the data on the spreadsheet to calculate the index led to the discovery of the formula.

PASSENGER WAIT INDEX

The waiting time measures are applicable only to frequent service when it is assumed that passengers go to the stop without expectations of boarding a particular bus at a particular time (i.e., that passenger arrivals are Poisson distributed). When passengers are oriented to a scheduled time, different calculation methods are needed. At headways of 10 min or more, regularity measures are probably less desirable than on-time performance measures, as reflected in the measurement practices of London Transport (*13*).

The passenger's wait is a function both of the scheduled headway and of the regularity of service. The average wait increases as service regularity decreases. This may not be obvious. If 10 buses arrive in 1 hr, the average headway is 6 min no matter how regularly their arrivals are spaced. However, waiting times take into consideration the fact that passengers continually arrive at a bus stop and that more are affected by longer than by shorter headways.

The formula for average waiting time commonly used in transportation analysis were developed by Welding (*3*) in 1957 and further elaborated by Holroyd and Scraggs (*2*) in 1966. The formula Welding gave for average waiting time $E(w)$ is

$$E(w) = \frac{\sum h_i^2}{2 \sum h_i} \tag{4}$$

where h_i is the set of observed headways (the time between buses). The proper application of this formula assumes that (a) passengers arrive randomly at the stop (as represented by a Poisson distribution), and (b) they can board the first vehicle that arrives.

An alternative formula, showing that the average wait is a function of the coefficient of variation, is given by Bowman and Turnquist (*4*):

$$E(w) = \frac{H}{2}(1 + C_v^2) \tag{5}$$

where H is the mean observed headway and C_v is the coefficient of variation—the standard deviation of headways divided by the mean headway (H). Therefore, C_v^2 is the variance of headways divided by H^2.

For example, for 10 buses scheduled in a 60-min period, the average headway is 6 min and the minimum average wait (under conditions of perfectly even service) is 3 min. However, if actual service is less than perfect, the actual average wait exceeds the minimum average wait. In Table 1, 20 different combinations are presented for sets of 10 headways covering 1 hr. Case 6 has an average wait of 7.8 min, calculated using Equation 5. The more evenly distributed Case 17 has an average wait of 3.35 min.

The average wait, though an extremely important measure for evaluating service, depends on the average scheduled headway; therefore, it is unsatisfactory for comparing routes. Planners at London Transit devised a measure that they called "standardized excess wait," which is mathematically independent of the scheduled headway (*5*).

The formula for standardized excess waiting time is

$$S = \frac{n - 1}{2nC} (\text{var } h_i) \tag{6}$$

where n is still the number of headways, and C is some constant, equal to the scheduled headway of the service, or the mean observed headway at a chosen base point on the route.

TABLE 1 TWENTY SETS OF HEADWAYS FROM MONTE CARLO SIMULATIONS

	Headway Rank										Measures		
Case	1	2	3	4	5	6	7	8	9	10	R	W	C_v
1.	0	1	1	2	2	2	3	4	10	35	0.34	0.26	1.67
2.	0	0	0	2	3	4	4	6	8	33	0.35	0.29	1.56
3.	0	0	0	2	2	2	7	8	9	30	0.35	0.33	1.44
4.	0	0	1	2	2	2	4	5	16	28	0.35	0.33	1.43
5.	0	1	2	3	4	4	5	5	5	31	0.45	0.33	1.42
6.	1	1	2	3	4	4	5	5	7	28	0.49	0.39	1.26
7.	0	1	1	1	4	6	7	9	13	18	0.49	0.53	0.94
8.	1	1	1	1	5	5	7	7	9	23	0.50	0.47	1.06
9.	0	1	1	3	4	4	7	9	13	18	0.50	0.54	0.92
10.	2	2	2	2	3	4	5	6	7	27	0.52	0.41	1.20
11.	1	2	3	3	4	6	7	8	8	18	0.61	0.63	0.77
12.	0	1	4	5	5	5	5	8	11	16	0.61	0.65	0.74
13.	0	1	2	4	5	7	8	9	12	12	0.61	0.68	0.68
14.	0	2	5	6	6	6	8	8	9	10	0.73	0.81	0.49
15.	1	2	4	5	6	7	8	8	9	10	0.73	0.82	0.47
16.	2	3	3	7	7	7	7	8	8	8	0.81	0.88	0.37
17.	3	4	4	5	5	6	7	8	9	9	0.81	0.90	0.34
18.	2	3	5	6	6	7	7	7	8	9	0.81	0.90	0.34
19.	5	5	5	6	6	6	6	7	7	7	0.93	0.98	0.13
20.	5	5	6	6	6	6	6	6	7	7	0.95	0.99	0.11

Source: New York State Office of the Inspector General for the MTA (Service Review Unit)

However, this measure returns to the problem of interpretation for the coefficient of variation. Although a value of 0 (indicating no headway variance) is clearly the optimum service, S has no upper bound and the measure is not expressed in minutes or any other concrete unit of measurement. Also, the measure is intuitively difficult for the nonspecialist to grasp because increasing values indicate declining service, creating difficulties in explaining results to public officials or even senior management. Moreover, the method of determining the constant C is not clearly prescribed, so different researchers might have different results. London planners do not use this measure for public reports; their reports use average wait and average excess wait, both expressed in minutes.

The passenger wait index addresses both problems of previous measures. It controls for the magnitude of the scheduled headway, and it is expressed on a scale from 0 to 1. This index is calculated as the minimum average wait divided by the actual average wait. Expressed in terms of the formula given by Bowman and Turnquist (*4*),

$$W = \frac{1}{1 + C_v^2} \tag{7}$$

Calculating W also identifies the proportion of the average wait that is greater than the minimum average wait. For example, if W equals 0.60, then the minimum average wait is 60 percent of the actual average wait. Taking the reciprocal ($1/W$) indicates that the actual average wait is 10/6 of the minimum wait. On average, passengers waited 67 percent longer than desirable.

HEADWAY REGULARITY AND PASSENGER WAIT INDICES IN PRACTICE

Figure 2 shows the regularity index and the passenger wait index for each route studied. The 15 routes are arrayed from least to most regular. All routes except the Bx55 were scheduled at nearly even intervals where the observations were made. The lowest scores were for the B46, M7, and B35 bus routes. The highest score was for the Bx30 route. After the schedule of the Bx30 was revised by the NYCTA, the R value reached 0.90 and the W value became 0.95. Before the schedule change, for the Bx30 the R value was 0.82 and the W value was 0.87, still higher than for any other route measured. That these measures captured the improved regularity demonstrates their relevance for evaluating operational and planning actions.

The low level of service for many of these routes is the result of many factors. The NYCTA schedules, route configurations, and supervisory practices must be considered as contributing factors. But other key causes of irregular bus service are external to agency operations; they are consequences of the social, economic, and political features of urban life. Measures of bus service quality therefore go beyond the responsibility of transit providers and reach to broader political issues and the decisions made collectively regarding the role of public transit.

Regularity measures offer a way to assess the inconvenience experienced by transit riders from all causes and provide a way to measure progress in improving transit service by means of broader environmental, planning, and development policies. The effectiveness of the NYCTA's operating and scheduling changes can be assessed with these measures and reported publicly. Assessment of the traffic control and parking enforcement policies of local urban transportation agencies on public transit service quality is also made possible. One measure for internal and external factors helps facilitate a unified effort.

In general, the measures are in agreement regarding the quality of service. The differences in values are explained in the next section. The implications for choosing one regularity measure over another are discussed in the conclusion.

INTERPRETING VALUES OF THE INDICES

In order to understand the headway regularity and passenger wait indices more fully, a number of sets of randomly generated headways were studied. Table 1 presents 20 of the

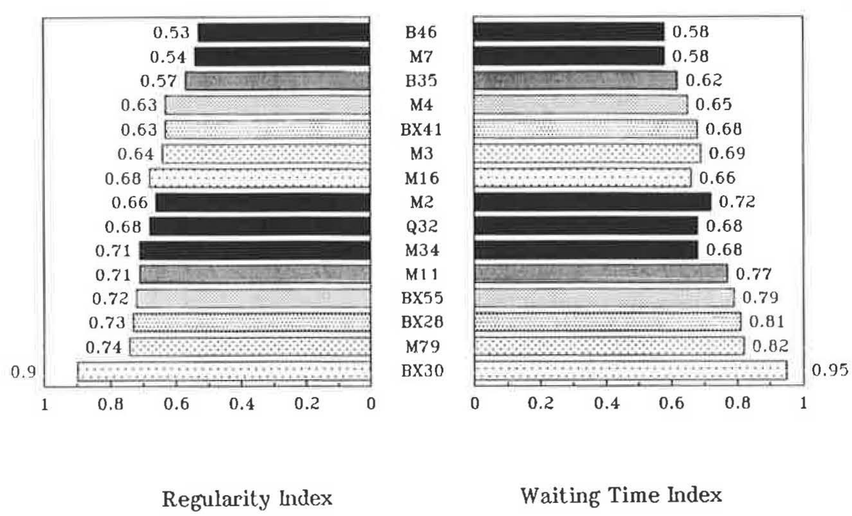

FIGURE 2 Midday performance for selected New York City bus routes. (Source: N.Y. State Office of the Inspector General for the MTA.)

thousands of cases generated, chosen to illustrate the behavior of the measures at different service levels. These cases are ordered from least to most regular, according to the regularity index. The headways are ranked from smallest to largest. The 10 headways in each set sum to 60 min. Cases 1 to 5 portray a level of service that is poorer than any bus routes yet observed. The headway pattern combines several bunched buses with one or more extremely large headways. The R values are 0.34 to 0.45, whereas the W values never exceed 0.33. The variance of the headways is large. This level of service is obviously not acceptable; both measures reflect this.

The service patterns in Cases 6 to 10 are similar to some patterns measured in practice that represent poor-quality service. When R is around 0.50, W can be either greater or less than R. Although it is not shown in Table 1, if W is held constant at 0.50 (when C_v is 1.0), R remains stable, varying only from 0.47 to 0.52. When $W < 0.50$, however, the R values can fluctuate considerably. For five cases (Cases 1 to 5) with $W = 0.33$, the R values ranged from 0.34 to 0.45. Outlying values—as in Cases 5 and 10—can have a large effect on the headway variance, and, consequently, on the wait index.

In Cases 11 to 13, the wait index begins to exceed the regularity index. In Cases 14 to 18, W exceeds R by a consistent amount, with the gap narrowing as both converge to 1.0 in Cases 19 and 20. The headway patterns grow consistently and obviously better, with C_v gradually tapering off toward 0.

In the cases presented in Table 1, $W < R$ when $R < 0.40$, and $W > R$ when $R > 0.60$. This pattern reflects the conditions of the simulation program more than mathematical inevitability. After many simulations, some of which were more consciously modeled as bus service, it became clear that W and R were typically about equal in the range below 0.45, after which W increased slightly more rapidly than R up to 0.90, when it tended to taper off. In all simulations, W exceeded R in the upper range of the scale, often as early as 0.60. In all simulations, the rate of increase for W began to decline after 0.90.

Figure 3 shows the differences in the rate of increase of the two measures. Beginning with Case 4 in Table 1 ($R = 0.35$, $W = 0.33$), 1 min was repeatedly transferred from the highest to the lowest headway until perfect regularity was achieved. One-minute transfers were used to analyze the behavior of the measure. This kind of micromanagement occurs in practice when dispatchers hold one of two bunched buses to redistribute the headway interval. Greater effect on the measure occurs when one bunched bus is used to split a large headway gap, also a common strategy of dispatchers.

The two measures were equal at 0.74, after which W is always greater (until both reached 1.0). The average rate of increase for R is constant, although it fluctuates from one step to the next and declines slightly for higher values of R. The rate of increase for W starts out lower than that for R, but it is an increasing function until 0.90, when it begins to decline.

The cause of this pattern is revealed by examination of the respective rates of change. For a set of headways (h_i with rank r_i, so that $i = 1, \ldots, n$), with values $x_1, x_2, x_3, \ldots, x_n$ and mean headway H, a transfer of d minutes from h_n to h_1 (i.e., from largest to smallest headway) will improve R by the following amount:

$$\Delta R = \frac{2d(r_n - r_1)}{n^2H} \simeq \frac{2d}{nH} \quad \text{when } n \text{ is large} \tag{8}$$

For the maximum change in R, $r_n - r_1 = n - 1$, the difference between ranks of the highest and lowest headways. The smallest change in R would be obtained by redistributing time between consecutive headways, so the difference in rank would be 1. For example, a redistribution from the largest to the next largest headway (see Cases 1 and 4 in Table 1) would make a smaller change. In this case, the numerator would include $r_n - r_{n-1}$, which is the same as $n - (n - 1) = 1$. Therefore, for the case of minimum change:

$$\Delta R = \frac{2d}{n^2H} \tag{9}$$

Differences in rank are not independent of the actual headway values, because higher levels of regularity are marked by many even headways. For example, in Table 1, a transfer of 1 min for Case 19 from highest to lowest would be from r_8 to r_3, a difference in rank of 5. Such a transfer for Case 5 would give 9 as the difference in rank ($r_{10} - r_1 = 9$). Therefore, as

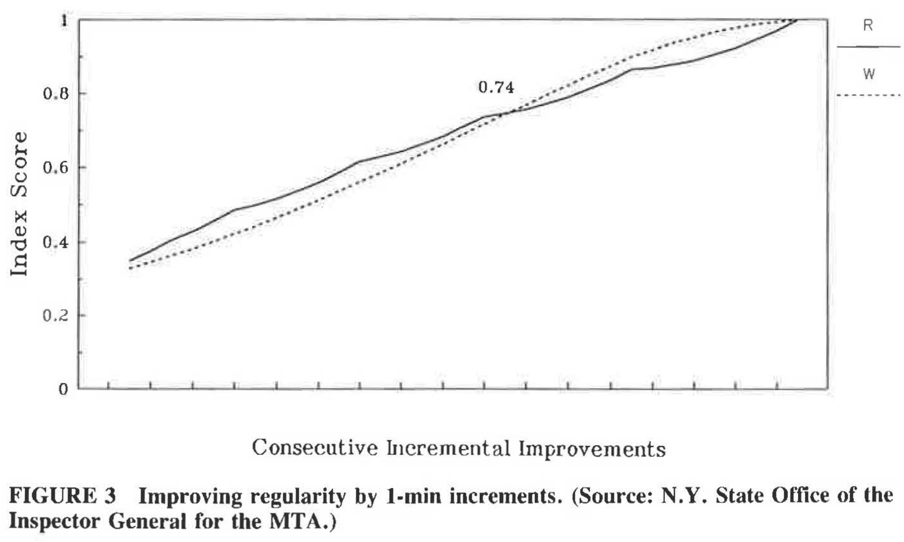

FIGURE 3 Improving regularity by 1-min increments. (Source: N.Y. State Office of the Inspector General for the MTA.)

R increases, the difference in rank between the headways involved in a transfer tends to narrow. The average rate of change at R therefore declines slightly as R improves.

The rate of change of W is less constant. Equation 10 yields the rate of change of the reciprocal of W, signified here as $1/W$. As the value of $1/W$ increases with better service [i.e., the difference between the largest (x_n) and smallest (x_1) headways gets smaller], the change in $1/W$ decreases. Because the numerator of the equation is always negative, a decrease in ($x_n - x_1$) causes the numerator to get larger (i.e., less negative).

$$\Delta(1/W) = \frac{2d[d - (x_n - x_1)]}{nH^2} \quad (10)$$

The formula for the rate of change of W is the following:

$$\Delta W = \frac{\Delta(1/W)}{[1 + C_v^2 + \Delta(1/W)]\,(1 + C_v^2)} \quad (11)$$

Figure 4 shows the rate of change for the wait index (W), for its reciprocal ($1/W$), and for the regularity index (R). A rolling average is used to iron out small fluctuations. The rate of change for $1/W$ is a nonlinear, constantly decreasing function, asymptotic to the x-axis. In the beginning, W increases about 0.017 with every minute transferred. W improves at a growing rate—depending on the value of C_v—to a maximum point; then its rate of increase declines. Between 0.70 and 0.90, the rate of increase peaks at 0.027 for every minute transferred. The value drops to 0.010 when W exceeds 0.97. The square of C_v in Equation 11 makes the rate of change for W a parabolic function.

CONCLUSIONS

Two measures of service regularity are presented here, the headway regularity index (R) and the passenger wait index (W). They are suggested as desirable measures of performance because they satisfy two conditions. First, they control for the mean headway, so they allow routes with different characteristics to be compared. (They are not independent of the mean headway in the strict mathematical sense.) Second, they are expressed on a normalized scale from 0 to 1.

Perhaps the most striking conclusion from comparative analysis of the two indices is the overall similarity of the results despite different calculation methods. Nevertheless, differences in behavior occur both for the values of the measures and for the rates of change. W is usually greater than R in the ranges of values corresponding to the bus routes studied, and W reaches values over 0.90 more quickly than R. When R is between 0.45 and 0.55, W provides more information than R about service levels. With W, Cases 6–10 in Table 1 can be distinguished, whereas with R they are lumped together. In a system where service is erratic, W may be more sensitive to improvement efforts.

However, once W reaches 0.90, it becomes more difficult to improve the rating. R, on the other hand, is slow to reach 0.90, but incremental improvements in regularity increase at nearly a constant rate. In Cases 19 and 20, a 1-min transfer from one headway to another increased R two points. R may be more appropriate for systems with good performance or situations for which it is possible to fine-tune the operations. W may be more adaptable to measuring change at lower levels of performance.

The different behaviors of the two measures reflect the fact that each measure emphasizes different aspects of service. They differ primarily in that the wait index is a function of the headway variance. All the waiting time indicators, including average waiting time, average headway, and the wait index, are more sensitive to outlying values and exhibit more nonlinearity than the regularity index.

The difference in emphasis corresponds to the distinction between an operational view and the passengers' view. For passengers, the extremely large headway should figure prominently in any account of performance. For operations managers, the size of the deviation is only part of the problem; the number of buses deviating must also be considered because it indicates the number of managerial interventions required to restore regular service.

Another practical consideration affects the decision regarding which index to choose. Because the wait index as-

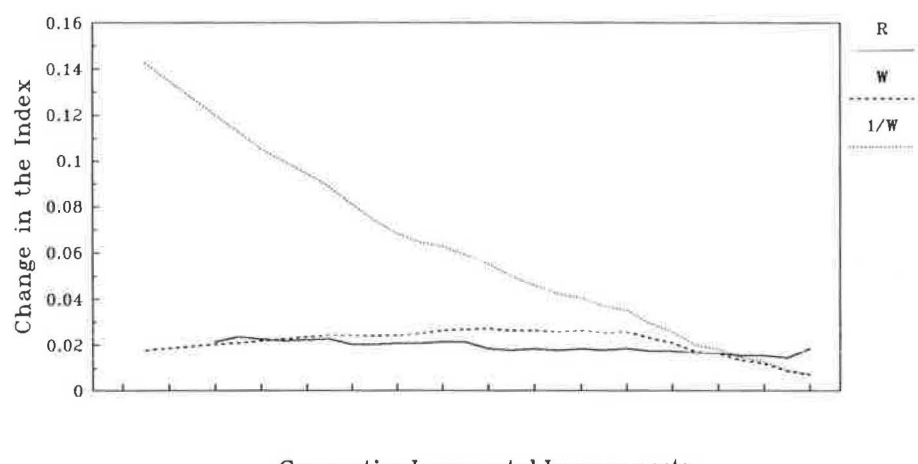

FIGURE 4 Changes in the regularity index. (Source: N.Y. State Office of the Inspector General for the MTA.)

sumes that the arrival pattern of passengers is Poisson distributed, it is inappropriate for infrequent transit services, when passengers can be assumed to know the schedule. Furthermore, its application becomes problematic when crowding is severe enough to violate the second assumption, that passengers can board the first vehicle that arrives. The regularity index is not hindered by these caveats because it refers exclusively to the headway distribution and ignores passenger arrival patterns.

A psychological dimension must be included in the evaluation of these indicators. The sensitivity of the wait index to extreme headways takes into consideration the riders' psychology. Although pertinent research is lacking, it seems plausible to assume, and it is consistent with personal experience, that after a long wait at a bus stop, each additional minute increases dissatisfaction with service disproportionately. Each additional minute's wait is increasingly frustrating and more conducive to anxiety about getting to one's destination or about whether the bus will ever come. Therefore, in Table 1, the wait index correctly rates Cases 6 and 10 worse than Cases 7 and 9. Similarly, it is appropriate that the rate of improvement in W should decrease after 0.90. At that level of regularity (see Cases 19 and 20 in Table 1), the improvement from a transfer of 1 min becomes difficult for passengers to discern, and small irregularities are less important.

On the other hand, a strictly operational measure should avoid such psychological arguments. The headway regularity index is more straightforward in this respect. Because its rate of change is more constant, it is preferable when used as a variable in multivariate analysis. Furthermore, the property of R of scale independence allows use of techniques for aggregating service at different time periods into a single composite measure. Aggregation with W may be more problematic. Finally, R is the only measure that can be used when it is known that passengers cannot board the first bus, unless other analytical techniques make it possible to calculate average wait under these conditions.

The values of the indices differed when applied to actual service. The value of W exceeded that of R for almost all routes. For many of the routes, however, both indices were low, signifying poor performance. For example, for the B46 route, both the R value of 0.53 and the W value of 0.58 clearly represented low-quality service as well as inefficient operation.

The issue of what score indicates a good level of service is more complex. Experience with a large body of empirical data would make the evaluation of service with these measures more meaningful. Once this type of data is acquired for a wide range of bus routes over time, analysts can group routes according to operating and environmental characteristics, and make comparisons between one route and another or between a given route last year and its performance this year. Such empirical data for route performance would also make it possible to set goals for individual routes that would serve as a basis for the evaluation of specific policies and managerial actions.

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Subway Reliability and the Odds of Getting There on Time

GARY HENDERSON, HEBA ADKINS, AND PHILIP KWONG

The most common service reliability measure—on-time performance—has drawbacks transit managers and consumers should be aware of. By converting on-time performance to odds ratios, a fresh look at what is meant by transit reliability is obtained. Although differences in on-time performance may seem slight, measurement with odds ratios can indicate quite different service levels. Transit managers, if they rely exclusively on on-time performance and do not heed the lesson to be learned from odds ratios, may be deceived when they estimate how much improvement can be achieved with a particular policy or action. The magnitude of effects will vary with level of effort, depending on the initial level of reliability.

Herein, reliability indicates timeliness (especially travel time), not the reliability of the rolling stock, infrastructure, or other separate components. In general, regularity measures are most useful in defining the reliability of high-frequency service, but the reliability of travel time is also a vital dimension of service. Timeliness of the passenger's trip is the end result of all the material and organizational aspects of transit service delivery; it is the consumer's experience at the point-of-service. Perhaps the most common performance measure in the transit industry for estimating timeliness is on-time performance. On-time performance is a useful and seemingly straightforward mathematical concept, but in some ways it distorts the perception of transit reliability. Reliability measurement can also be done by transforming on-time performance into odds ratios, the odds of being on time. Adopting this concept of the gambling industry can reveal aspects of transit reliability relevant both to transit operators and to passengers.

ODDS OF BEING ON TIME

A statistician thinks of on-time performance as on-time probability. The percent of trains arriving on time is another way of saying the probability that a given train will arrive on time. Although trains can be late by varying amounts, there are no different shades of being on time. Once a standard is chosen, e.g., 5 min, every arrival, on the basis of this cutoff, can be classified as being late or being on time. On-time probability is a yes or no proposition, just as flipping a coin is heads or tails. A value of such a binary variable can be calculated as a ratio of successes to failures (of on-time to late trains). This value is known as an odds ratio.

For example, if 220 of 250 trains arrive on time, the on-time probability is (220/250 = 0.88, or 88 percent). The on-time odds are the ratio of on-time trains to late trains, 220/30 or 7.3 to 1. This ratio is the same as that of the on-time probability to the late probability (0.88/0.12 = 7.3). In mathematical terms, if P is the probability of being on time and $1 - P$ the probability of being late, the odds of being on time are $P/(1 - P)$.

On-time performance increases linearly, whereas the odds of being on time increase geometrically. If there are 250 trains, every on-time train contributes 0.4 percentage point to on-time performance. So, if instead of 220 on-time trains, an operating adjustment makes it possible for 240 trains to arrive on time, on-time performance increases 8 percentage points (20×0.4), from 88 percent to a new level of 96 percent. On-time performance improved by 8/88, about 9 percent. The odds, however, increased from 7.3:1 to 24:1 (240/10). Reliability as measured by the odds improved by about 230 percent [(24 − 7.3)/7.3].

Figure 1 shows the relationship between on-time probabilities and odds. The line starts at 50 percent, at which the odds are 1:1. Below 50 percent on time, it is more appropriate to speak of the odds of being late, which is an identical curve, but inverted in the range from negative infinity to negative one. The rate of change (as measured by the slope of a line drawn tangent to the curve) around 60 percent on time is smaller than the rate of change at 85 percent. The odds are increasing slowly at 60 percent on time; but as on-time performance steadily improves to over 85 percent, the rate of change increases sharply.

In fact, probabilities and odds say the same thing in different ways; for the statistician, probabilities are usually the expression of choice. However, in describing transit reliability as passengers experience it, the odds ratio may be the measure that is in best accord with rider psychology.

Furthermore, when transit managers determine what actions or investment of effort or resources will improve on-time performance and wish to measure the size of the effects these actions will achieve, they prefer to consider odds ratios. This process also requires statisticians to determine the best technique for measuring the strength of causal factors in improving reliability.

PASSENGERS' VIEW

The average passenger is not likely to conceive of the likelihood of arriving on time in the mathematically abstract terms of probability. The odds of being on time are more in harmony with the concrete experience of riders. Recently, the New York State Office of the Inspector General for the Metro-

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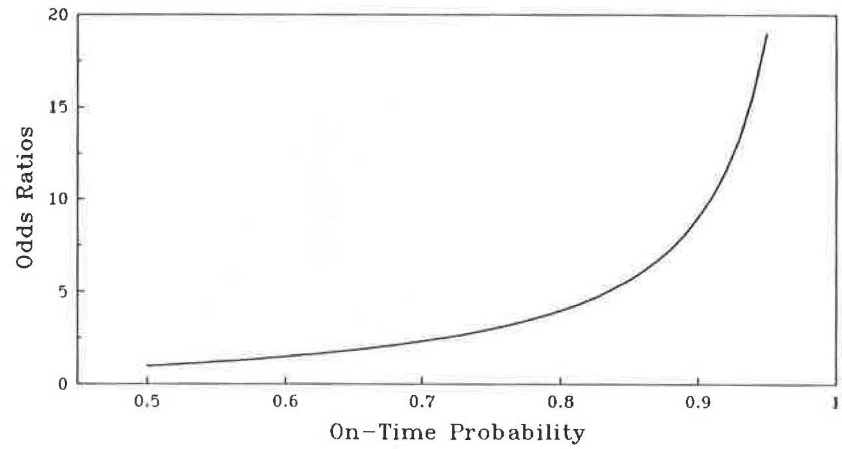

FIGURE 1 Odds ratios compared with probabilities. [Source: N.Y. State Office of the Inspector General for the MTA (Service Review Unit).]

politan Transportation Authority (MTA) monitored waiting times for the Brooklyn B35 and B46 bus routes (*1*). *The New York Times* interviewed passengers and reported that riders thought of catching the B46 bus as the "lotto wait." The "chances of a (B46) bus . . . running on time are about the same as winning the lottery" (*2*).

Odds ratios are represented in the most basic terms: how many days is the rider on time compared with how many days the rider is late. For example, a rider may recognize that he or she is late, say, once a week, which translates to being on time 4 days for every 1 day late, an odds ratio of 4:1. If on-time performance is 60 percent, passengers are on time 3 days and late 2 days in a 5-day week, a 3-to-2 chance of being on time. At 80 percent on time, riders are late 1 day a week. At 90 percent on time, 1 day in 2 weeks (more than double the reliability of the 80 percent level). Above 90 percent on time, a change in on-time performance has an enormous effect on the odds. For example, at 95 percent on time, riders are late once in 4 weeks. At 96 percent on time, riders are late once in 5 weeks; at 97 percent, once in 6½ weeks; and at 99 percent on time, only once in 100 work days, a little more often than twice per year. At such high levels of on-time performance, passengers are late so infrequently that they may not even remember the last time they were late.

Some examples from a report by the inspector general for New York's MTA will illustrate the situation (*3*). Evaluating 1988 morning rush hour subway service, the inspector general's report found that the D/Q Manhattan-bound route was 58 percent on time, 9 percentage points higher than in 1987, whereas the L Manhattan-bound route was 80 percent on time in 1988, 9 percentage points lower than in 1987. Although the magnitude of change of the on-time performance of the two lines was the same in terms of percentage points, the difference in the change in reliability was great. Figures 2 and 3 show that the change in the odds of being on time for the D/Q line was minimal—from 1 to 1.4—whereas the reliability of the L line declined by more than 50 percent—from 8.3 to 4.1.

A number of interesting conclusions can be made from the foregoing discussion. First, the difference in the quality of service between a transit service that is 70 percent on time (six times late in 4 weeks) and one that is 95 percent on time (once late in 4 weeks) is extremely large. Reliability for the latter is eight times better, because the odds at 70 percent on time are 7:3 whereas the odds at 95 percent are 19:1, or 57:3. Another implication is that when on-time performance is at a mediocre level, a large percentage point improvement is needed to make an impression on passengers. When on-time

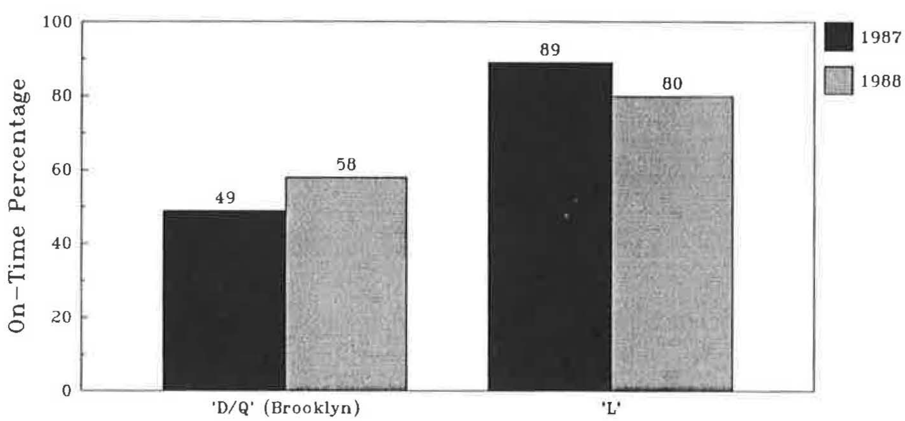

FIGURE 2 On-time percentage for the D/Q and L lines. [Source: N.Y. State Office of the Inspector General for the MTA (Service Review Unit).]

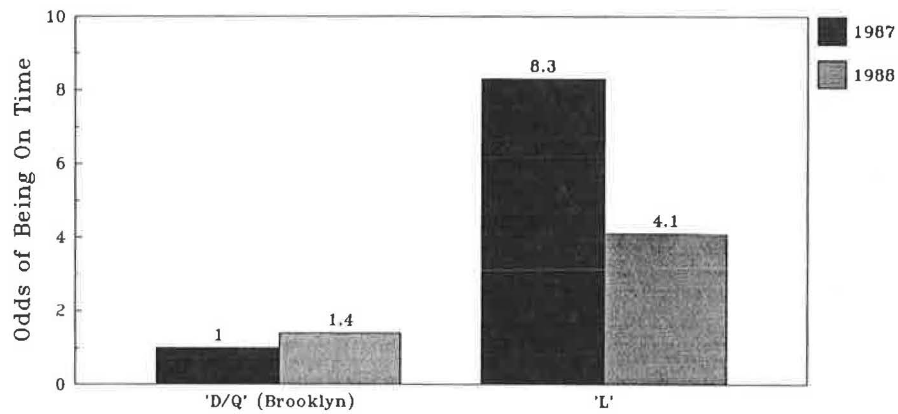

FIGURE 3 Odds ratios for the D/Q and L lines. [Source: N.Y. State Office of the Inspector General for the MTA (Service Review Unit).]

performance is high, small percentage point improvements in on-time performance have a great impact. However, as will be seen, the higher the level of reliability, the more resources are needed to improve on-time percentages.

TRANSIT MANAGER'S VIEW

It has been noted that small changes in on-time performance are more noticeable to passengers at higher levels of performance. The improvement from 95 percent to 98 percent—for which the odds of being on time increase 2½ times from 19:1 to 49:1—requires a level of effort (in terms of investment, operating costs, or degree of change in service configuration) similar to that needed to improve on-time performance from 60 to 79 percent—for which the odds are 1.5:1 and 3.8:1, respectively. Just as a change in on-time performance from 95 to 98 percent is more significant for passengers than a change from 60 to 63 percent, this improvement requires significantly more resources to achieve, all other things being equal. Lines operating at the 95 percent level of on-time performance have few major equipment, infrastructure, or crew problems; lateness of trains is caused by much more subtle problems or by random occurrences. However, at the lower levels of reliability, an improvement in a major area would affect a large number of trains and significantly increase reliability.

This fact has implications for any operational program for improving reliability. Clearly, the greatest payoff can be realized by working on the worst lines (as long as they are not too bad). If reliability is considered the result of a variety of policies or operating inputs, the same effect may not result from the same level of effort. Using the jargon of the statistician, if reliability is the dependent variable in a causal model with a variety of other independent variables (e.g., mechanical reliability, track condition, service configurations, headways, and passenger loads), the relationship of reliability to each of the many causal factors is not a linear one.

The statistical reason for this is that on-time probabilities are not continuous variables. They can increase or decrease only within a restricted range—from 0 to 1. In order to use on-time performance as a continuous variable, it must first be transformed so it will have an infinite range, as with the technique of logistic regression (*4*). To ensure that there is no upper bound to restrict improvement in performance, on-time probabilities are converted to odds ratios. Odds ratios stretch from zero to positive infinity. To ensure there is no lower bound, the odds ratios are transformed into logits by taking their natural logarithm.

$$\text{logit} = \log_e \frac{P}{1 - P}$$

Logits extend from negative infinity to positive infinity. When the odds are exactly even—at 50 percent on time—the logit of on-time performance is 0. As shown in Figure 4, below 50 percent on time the logit is negative; above 50 percent on time, it is positive. The negative sign is appropriate, because below 50 percent on time, the likelihood is greater that riders will be late than on time. Figure 4 shows the nonlinear relationship between on-time performance and logits of on-time performance. The changing slope of that curve indicates the changing degree of difficulty to improve reliability at different levels of reliability.

In order to demonstrate how such a model would work, the results from a preliminary causal model of subway performance can be examined using logistic regression. This model uses a few key variables like headway, mechanical reliability, merges, number of stops, etc., not by any means a comprehensive set. Because the coefficients from the techniques of logistic regression are different, depending on the starting condition, it was estimated that an increase in headway of 1 min would improve on-time performance by almost 5 percentage points for a route at 50 percent on time, but only 1 percentage point for a route at 95 percent on time. Similarly, the addition of one merging route would decrease on-time performance 14 percentage points for a route at 50 percent on time but only 2.5 percentage points for a route at 95 percent on time. These coefficients are given not as valid estimates of the effects of these actions but rather to demonstrate the variability of the effect. A study to estimate the strength of such factors is in progress, and this effort will include a more comprehensive set of variables and a larger sample of data.

Figure 4 also shows that when performance is below 10 percent on time, a huge investment would be required to

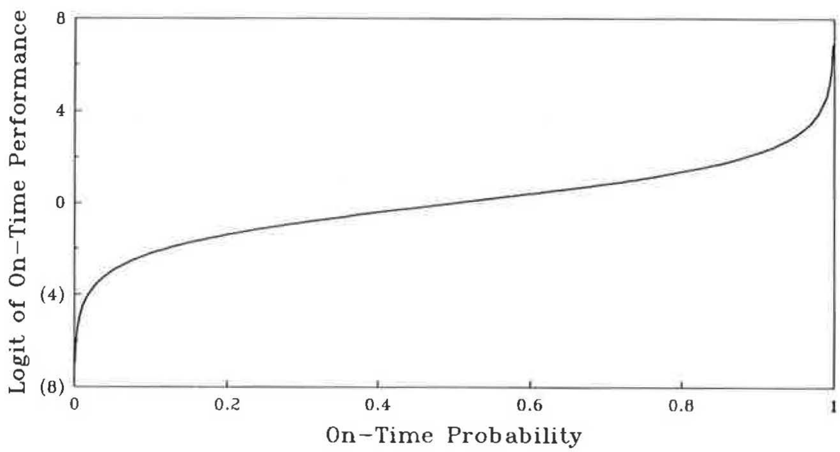

FIGURE 4 Logit curve for on-time performance. [Source: N.Y. State Office of the Inspector General for the MTA (Service Review Unit).]

improve performance. How could performance be so poor unless the infrastructure is in total disrepair, the rolling stock completely antiquated, or the workers utterly demoralized? When it is 50 percent on time, the slope is about level, suggesting that the greatest impact on reliability for a given level of effort can be achieved. Above 90 percent on time, the reliability logit rises steeply, indicating that additional investment will have diminishing returns.

The shape of this curve also has implications for performance goals for transit services. When performance is in the middle range (20 to 80 percent on time), large improvement in the on-time percentage is possible with the least amount of change in effort. When performance is above 90 percent, small percentage increments in on-time performance are significant and only small improvement may be possible. Therefore, operators need to set different targets for on-time performance for different lines depending on the operating conditions and resources available for each line. Performance above 95 percent may be an unrealistic goal for most routes, especially where merges and crowding are factors.

CONCLUSION

Service reliability is most commonly defined by the on-time performance of an operation. However, on-time probabilities hide the 1,611 effects of service performance on passengers. On-time performance percentages are less concrete and expressed less in daily real-life terms than ratios of how often passengers are late versus how often they are on time. By transforming on-time probabilities into odds ratios, transit operators can more effectively measure the reliability of the service delivered from the passengers' point of view. Odds ratios are more intuitively meaningful to passengers than on-time probabilities, as well as being operationally relevant to operating agencies. Using odds ratios, operators can determine how to allocate their resources to achieve the greatest payoffs.

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TransitTopics: Boston's Neighborhood Transit Service Workshop Program

SUSAN BREGMAN AND MARY STANTON HYNES

Transit providers need to hear directly from their users how everyday transit service can better address their needs. TransitTopics is a program undertaken over the past 3 years by the City of Boston's Transportation Department. The department sponsors neighborhood workshops to enable residents to discuss transit service issues. Comments and recommendations made by workshop participants are consolidated in a report and distributed to the public and Boston's regional transit agency, the Massachusetts Bay Transportation Authority (MBTA). The workshops have served as a forum for residents to discuss their concerns, and this has provided insight into transit service problems, along with recommendations for areawide and neighborhood-specific improvements. Suggestions have included bus route alterations to serve identified needs and new bus shelter locations. Key findings are that citizens very much appreciate speaking directly with public officials and will respond constructively in a structured setting. In addition, beyond giving credit for positive service changes, they offer a wealth of observations and opinions about transit and workable solutions to address specific problems. The program has also provided a strengthened working relationship between the city and the MBTA.

The Boston Transportation Department (BTD) developed the TransitTopics program in 1988 to give neighborhood residents a greater voice in transit planning decisions. The highlight of the program is a series of workshops held in city neighborhoods each year to discuss local transit service issues, such as frequency and hours of service or route structure. Workshop comments and recommendations are consolidated in a report distributed to the public and the regional transit agency.

The program was designed to complement ongoing efforts by the city and the Massachusetts Bay Transportation Authority (MBTA), the regional transit agency that serves Boston and the surrounding metropolitan area, to discuss transportation needs and projects. Although opportunities exist for community participation on major capital projects, there is often little occasion for transit riders to relate their concerns about everyday service. TransitTopics bridges this gap by creating a forum for transit users to communicate directly with public officials.

The city, which has conducted the program since 1988, considers TransitTopics an important part of its transportation planning and advocacy role. The program has become a critical input to the city's annual recommendations to the MBTA, and the transit agency has been a positive and active participant in the program since its inception.

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BACKGROUND

Role of Transit in Boston

Public transportation plays a crucial role in supporting the social and economic vitality of Boston's neighborhoods, its commercial and industrial centers, and its downtown. In addition to being an essential part of the city's infrastructure, transit also serves the surrounding greater Boston communities. It provides commuters from outlying cities and towns with an alternative to automobile travel, removes a significant amount of traffic from city streets, and reduces the demand for a limited parking supply.

Many city residents rely on transit for work, school, shopping, and recreation trips. One out of three Boston residents depends on transit to get to work. About 70 percent of city residents work within the city boundaries; about 45 percent work in their own neighborhoods or downtown. Transit provides important connections for these residents to the economic opportunities provided in the downtown and with the thriving commercial districts in their own neighborhoods. This access is especially important for the 39 percent of Boston residents who do not own a car.

The MBTA provides an array of transit services throughout the Boston metropolitan area. It operates rapid transit and light-rail services (known as the Red, Orange, Blue, and Green Lines), as well as an extensive network of bus routes. In addition, it operates commuter rail lines, express buses, and commuter boats, which principally serve suburban residents who work in the Boston core; and it provides specialized door-to-door transit services for the handicapped. In recent years, the MBTA has made a number of significant improvements to this transportation network, such as new and extended fixed-rail lines, major equipment purchases, and track and signal improvements.

In order to help support the costs of providing public transit services, the City of Boston pays close to $50 million each year to support MBTA operations. This represents 42 percent of the total contributed by municipalities in the region; it is also a significant portion of the city's budget. Given the size and importance of this investment in the city and region, the city believes it is crucial that residents and other users receive high-quality transit services that meet their needs.

City Transit Policy

As part of its overall planning efforts, BTD has developed a number of programs and policies designed to encourage increased use of public transportation.

Although the city does not provide transit service directly, city officials work closely with the MBTA to ensure the best possible transit service for Boston and its residents. As a member of the advisory board to the MBTA, the city plays a key role in reviewing the MBTA's annual operating budget. (Representatives of the 78 cities and towns served by the MBTA sit on the advisory board.)

In addition, city officials participate in numerous MBTA long-range planning efforts for major construction projects. In many cases, city representatives serve on project advisory committees or present testimony at public hearings. At other times, the MBTA asks the city to review project plans.

In contrast, there have been few comparable opportunities for city officials to have a voice in identifying transit service problems. Because its role has been generally limited to reviewing MBTA proposals, the city rarely has had an opportunity to initiate planning for new transit services. In the past, constituent complaints about MBTA service were usually forwarded to the appropriate MBTA officials. The city had no other formalized way to address these concerns.

Although similar opportunities exist for residents to participate in longer-term transit planning efforts (again, particularly related to larger capital projects), city residents also have few occasions to identify everyday transit service problems and needs.

Yet, it is these day-to-day aspects of transit service that touch the lives of Boston residents most directly. The reliability of bus services, the cleanliness of stations, the helpfulness of drivers in giving information to riders, and other service aspects are the most immediate and abiding contacts between the transit system and its users.

The TransitTopics program provides an avenue for users to comment on how the system meets their needs. TransitTopics serves two major goals:

- It provides a voice for the neighborhoods in articulating transit service needs and opportunities for improvement, and
- It helps the city formulate an agenda and establish priorities for transit service improvements to pursue them with MBTA.

The TransitTopics program gives neighborhood residents and business representatives an opportunity to receive information about the transit services in their neighborhood and, more important, to articulate their perceptions of the transit service problems and needs of their areas. Through this process, the program can identify the priority issues and needs within the local neighborhoods along with systemwide issues.

IMPLEMENTING THE PROGRAM

Program Development

In 1988, BTD initiated the pilot program for TransitTopics. In April of that year, the city invited community leaders to a reception to introduce the program and to garner their support for the upcoming workshops in their neighborhoods. Mayor Raymond L. Flynn was the keynote speaker at the event, voicing his commitment and enthusiasm for the program.

For the pilot program, workshops were held in a representative group of neighborhoods. Some areas had a high proportion of transit-dependent residents (on the basis of automobile ownership, income levels, etc.). Others were generally well served by the MBTA, but a few improvements were in order. Still others were facing potentially disruptive highway construction projects, and mitigating transit programs were being planned. Nine workshops were scheduled in the summer of 1988. By combining two sets of neighborhoods with similar transit service and demographic characteristics, 12 of the city's 16 neighborhoods were covered in the first year of the program.

Before the program's second year, BTD staff developed a long-range plan to ensure that neighborhoods were covered regularly and that city council districts were covered equitably. On the basis of this plan, a more focused second-year effort was undertaken, and workshops were held in four neighborhoods. In 1990, during the program's third year, BTD met with residents in six neighborhoods.

Meeting Notification

After the meetings were scheduled, BTD began the public notification process. Letters of invitation were sent to community residents, neighborhood organizations, and elected officials. In addition, meeting notices were posted at local community facilities and public buildings, and press releases were sent to local and citywide media.

Workshop Format

Meetings were kept as informal as possible. They opened with welcomes by city officials and acknowledgment of the presence of any elected officials and MBTA representatives. After a brief presentation about neighborhood demographics and transit services, the workshop facilitator discussed the ground rules. Agreed-on ground rules included the following:

- Concerns should relate to transit service issues rather than major capital projects or minor maintenance complaints,
- Everyone would have an equal opportunity to speak,
- No one would be permitted to dominate the discussion,
- All points of view would be welcomed,
- Speakers should stick to the point, and
- All would keep their comments as short as possible.

Here the facilitator pointed out that silent people would be drawn out, and difficult or hostile behavior was discouraged. She said that the focus was to turn complaints into suggestions and priorities, and she urged people to be realistic and constructive about their expectations (e.g., they were to avoid impractical proposals of monorails or new routes in areas where there was limited ridership).

After handing out index cards and requesting participants to write down what they considered their three most important transit service issues, the facilitator opened the discussion. Then, as the facilitator went around the table or room, each person was asked to present the first concern on his or her list, to be recorded on flip charts. The aim was to conduct a

1-min description of a particular issue, with the facilitator stepping in to move the discussion along when participants got bogged down in too much detail or disagreement.

The facilitator repeated the procedure, asking individuals for their second and then third points on their index cards, discussing specifics briefly with the group, and then proceeding to the next person. By moving on in this way, the facilitator could avoid having only a small number of people monopolize the discussion or cut short unnecessarily long discourses.

Frequently, participants would highlight the same issue. These concerns were designated on the flip charts with stars, especially if others voiced their agreement. Both sides were recorded if opposing viewpoints were expressed. For example, in one neighborhood, a few people were interested in changing the terminus of a bus route, whereas others felt that the existing route served the neighborhood well. Both comments were recorded initially, but ultimately the entire group did not agree on this as a priority.

The flip charts were used to record every comment, which helped organize the discussion and focus it on the major topics of concern to residents. In one meeting, where there was a large number of attendees, participants were divided into two discussion groups to give everyone ample opportunity to speak.

After about an hour, residents were asked to review their comments and set priorities. In early meetings, residents often insisted that every suggestion was a priority and that they simply could not choose among them. In order to focus the decision-making process in subsequent meetings, participants received three colored press-on dots. They were asked to place the dots, individually or in combination, next to the issues they considered to be their priorities.

Finally, the facilitator summarized the newly established priorities, thanked residents for their participation, and described the next steps in the process. These include BTD's consolidating the recommendations from the different neighborhoods into a summary report of each year's program findings, and submitting these service recommendations to the MBTA for review and response.

Role of the Facilitator

The facilitator plays a key role in the workshops. The meetings specifically do not encompass a long detailed technical presentation, and they are designed to avoid direct question-and-answer sessions between the city, MBTA, and residents. The focus is on what residents and users have to say and how they feel the system can better suit their needs.

The facilitator also works carefully at steering the conversation away from putting MBTA observers on the spot and away from topics that are not appropriate for the workshop. Typically, these are areas that are not related directly to daily service issues.

Some issues may be too large. For example, adding new fixed-rail lines or stations is not an appropriate area of discussion for TransitTopics workshops because the feasibility studies or environmental impact statements for large capital projects have their own public involvement process.

Conversely, some concerns are too small (such as a single broken bus heater or vandalized bus stop sign). For the latter category, individual complaints are recorded on index cards and forwarded to the appropriate MBTA department. In addition, for workshops where there were a number of such complaints, systemwide maintenance is listed as a separate issue in the meeting summaries.

Workshop Materials

Workshop participants receive a TransitPak consisting of the following materials: (a) a 15-page summary of neighborhood demographic characteristics and transit services prepared by BTD for each meeting; (b) a neighborhood map showing current transit routes and stations, again prepared by BTD; and (c) an assortment of MBTA informational materials.

Demographic information is drawn from the U.S. Census, updated when necessary, on the basis of city data. This information includes the total residential population of a neighborhood and its proportion of the city's population. Because people of different age groups have different transportation needs, population is also subdivided by age: school-age children (under 18 years), adults (18 to 64 years), and elderly (65 years and over).

Data are also included on automobile ownership to indicate dependence on transit. In order to further illustrate the relationship between work trips and transit, information is presented on how employees travel to their jobs and the general location of those jobs.

Information about transit ridership is also included. Boarding counts for buses and rapid transit services are drawn from statistics compiled by the MBTA. Ridership at neighborhood transit stations and on local bus lines is compared to other services throughout the city. Information about fares and special services is also included. MBTA schedule cards for buses in each community are reproduced for the packets. Finally, each packet includes a listing of useful addresses and telephone numbers for the City of Boston and the MBTA, such as the MBTA's service information representatives, its complaint or commendation number, and the city's neighborhood coordinators.

Bus routes and transit lines are illustrated on a separate map included in the packets. A larger version of the map is also prepared for the group discussion. MBTA materials distributed in the TransitPaks include full- and pocket-sized system maps and information on special needs services, commuter rail operations, fares, and the prepaid monthly pass program.

Program Transition

The city initially contracted with a consulting firm to help develop the program. The goal was for BTD to design a pilot program with technical assistance from consultants and then carry it forward, with BTD staff undertaking all the elements on a continuing basis.

The consulting firm worked with city staff to develop the pilot program: formulating a strategy, running the meetings, designing materials (primarily handouts and maps), coordinating logistics and format, and preparing the final report.

Pleased with the response to the first year's workshops, BTD officials incorporated the program into ongoing in-house planning efforts. Since the first year, BTD staff members have been successfully running the meetings and managing the program. In order to prepare staff to do so, the department contracted with the original consulting firm to run a 2-day training session covering meeting facilitation and oral presentation skills.

PROGRAM RESULTS

Program Findings

The workshops have provided many insights into transit service problems, along with recommendations for area-wide and neighborhood-specific service improvements. It was clear from the start that transit is a topic of great interest and importance to city dwellers and workers. Almost all participants have a wealth of observations and opinions about transit, and some have formulated solutions to address specific problems.

Some underlying themes quickly emerged, and they have remained consistent over the 3 years of the program.

- Citizens much appreciate the opportunity to communicate their observations, concerns, and recommendations about transit service to those responsible for bringing about improvements.
- Riders often see the MBTA personnel that they encounter daily as individuals. However, there is often confusion about the system and the different jurisdictional responsibilities among agencies. Ultimately, residents are not sensitive to the bureaucratic process; they simply want to see their problems addressed.
- Many citizens acknowledge the improvements that have been made in recent years in transit facilities and services, but they expect more to be done and more quickly. People are particularly puzzled and frustrated that apparently simple solutions to small problems can go unimplemented for years; and they are confounded by long delays in decisions and implementation of key transit service improvements.

The encouraging aspect of these themes is that even small actions that yield service improvements are likely to be recognized and appreciated by riders. In turn, there is hope that better service will foster more positive attitudes toward the MBTA. In fact, initial concerns on the part of both the city and the Authority that workshops might serve as forums for riders' frustrations, without generating constructive suggestions, were not realized.

TransitTopics in Action: Two Examples

When developing the TransitTopics program, most of the workshops were expected to focus on specific local issues. Plenty of these did come up in the discussions such as crowding on a particular bus route, lack of coordination between bus and commuter rail schedules, and the need for a passenger shelter at a busy bus stop.

But it was quickly discovered that residents saw the program as an opportunity to tackle issues that crossed neighborhood lines as well such as the need for better maintenance and security at fixed-rail stations, a desire for improved access to service information, and the wish for more outreach and accountability on the part of the MBTA.

Highlighted in the following paragraphs are two specific concerns raised at TransitTopics meetings and the MBTA response to each. One concern focuses on a neighborhood bus route, and the other identifies a systemwide problem.

Example: Mattapan Bus Service

The first TransitTopics workshop was held in June 1988 in Boston's Mattapan neighborhood. At the time, eight bus routes ran through the area. Most served Mattapan Square, the major commercial district, and provided connections to either the Red or Orange rapid-transit lines.

Connections to the Red Line were quite direct, with an estimated one-way bus trip at 11 to 12 min. Passengers transferring to the Orange Line were not so fortunate. Although the line's southern terminus, Forest Hills, is only 10 to 15 min from Mattapan Square, local bus routes connected with two stations farther north. Schedule cards estimated bus travel time on these congested routes to be 23 to 41 min.

Residents asked the MBTA to provide a direct bus connection between Mattapan Square and Forest Hills. They asked the MBTA to pay particular attention to early-morning connections between bus and subway, noting that many neighborhood residents use the Orange Line to reach their jobs in downtown hotels and restaurants. Quite a few of them must be on the job by 6:00 a.m., but existing connections to the Orange Line could not guarantee this access.

In response to these requests, the MBTA examined bus service in the Mattapan corridor. After reviewing ridership patterns, the MBTA determined that a new bus serving Forest Hills, in conjunction with reconfiguration of existing routes, could improve connections to the Orange Line without requiring additional resources.

The MBTA proposed a new bus route between Mattapan and Forest Hills with a trip time of 10 to 19 min, depending on traffic. The schedule ensures that passengers can easily connect with the first few Orange Line runs of the day, both before 5:30 a.m., enabling them to reach downtown by 6:00 a.m.

The MBTA first announced these proposed changes in September 1989 at a public meeting cosponsored with BTD, where residents were asked to comment on the proposal. Other MBTA hearings followed, and the changes took effect in December of that year. Public response has been mixed. Although passengers appreciate the new service to Forest Hills, those depending on other bus routes in the corridor feel that their service has been cut back too severely. As part of its ongoing review process, the MBTA will continue to look at service in this area and make refinements if warranted.

Example: The Bus Stops Here

Poor information and communication were among the most frequently and strongly voiced criticisms of transit service at most of the workshops. Patrons were especially critical of the lack of service information and asked the MBTA to make maps and schedules more widely available. In particular, signs at all bus stops, with information about routes and schedules, were recommended.

Admittedly, the plea for better informational signage did not originate with the TransitTopics program. This issue has been of long-standing concern, and transit advocates throughout the region have been seeking improvements for some time.

A local transportation management organization recently produced maps and schedules for area bus services, posting them at MBTA bus stops. Subsequently, a newspaper editorial praised these efforts and called on the MBTA to do the same throughout the region. Through the TransitTopics program, the city added its voice to those requesting that this issue be addressed.

The MBTA introduced its pilot bus stop signage program in spring 1990. During the first phase of the program, implemented during National Transportation Week, new signs with schedule and route information were placed along six bus routes. Informal feedback from the pilot effort has been positive. The MBTA currently has plans to evaluate the program's effectiveness; program expansion is pending a favorable review.

PRACTICAL LESSONS

Much has been learned from running TransitTopics meetings over the last 3 years—about meeting logistics, publicity, and atmosphere. Although TransitTopics was the forum, the lessons can be transferred to virtually any public meeting.

- You can never publicize a meeting too much. No matter how extensive you know your publicity has been, someone will criticize you for not giving adequate notice.
- Try to reach people where they live. Not everyone is on an official mailing list, and not everyone reads the local newspaper. This year, for the first time, notices were sent to community organizations for inclusion in their monthly calendars. Next year, an attempt will be made to take the advice of this year's meeting participants and work through local churches to publicize meetings.
- Make sure people can get to the meeting. Not only is it essential to ensure that the meeting place is accessible to those with mobility impairments, but it is important to think about the time of day. Many elderly citizens are reluctant to attend meetings outside their homes at night. If you want to hear from seniors, schedule a meeting during the day or hold the meeting at a regularly attended location.
- Consider cosponsoring the meeting with local civic groups. This gives the program an implied endorsement—and additional publicity.
- Confirm the meeting room on the day before. It sounds obvious, but it is also easy to overlook until you encounter a locked door on a sweltering June evening. Once, the mistake was made of asking someone else to confirm the reservation—and disaster was narrowly averted.
- The optimum meeting size is 15 to 20 people. This allows free participation and generates a wide range of ideas and issues. If the session is too much smaller, issues may not be representative; larger, and the group becomes unwieldy.
- A trained facilitator is essential to the success of the meeting. He or she will keep the meeting focused on producing positive and constructive suggestions, draw out reluctant participants, prevent others from dominating the discussion, and generally keep things moving.
- A defined meeting structure can help avoid a disorganized and chaotic complaint session. A set agenda, including a specific timetable for each segment, will give the facilitator the tools to run the meeting effectively. Dry runs are particularly helpful.
- Always follow up on questions. Nothing reinforces people's frustrations with government agencies faster than failure to follow up on a request or a question. Sadly, many people have become cynical about government officials. Following up on requests or questions belies those suspicions. Additionally, people are appreciative (and usually surprised) with a phone call the next day to answer a question or provide some information.
- Keep the meetings open, informal, and honest. A sense of humor helps keep things in perspective, and informal refreshments can help set a positive tone.

PROGRAM EVALUATION

The TransitTopics program has successfully brought together representatives from the city, the MBTA, and the community in an open planning process. But, as with any new program, there is still room for improvement. Discussed in more detail in the following paragraphs is experience with public participation.

Neighborhood Participation

Over the last 3 years, attendance at TransitTopics meetings has ranged from a low of 3 to a high of 35. Although the numbers of workshop participants were small relative to the resident population and the transit-riding public as a whole, their comments represent the views of citizens who are intensely concerned about transit service improvements for themselves and their communities.

In general, participation has been dominated by a few familiar faces—people who are active in several organizations and attend most community meetings. Frequently, these participants conveyed the views of local civic groups and neighborhood associations. In this respect, those who participated can be viewed as reflecting the weight and depth of citizen concerns and offering guidance to city policy makers. But the intended strategy of attracting transit users who may not participate regularly in other civic activities has not been entirely successful.

Drawbacks to good attendance can include a range of reasons unrelated to program design. Some residents may have no specific concerns about transit service overall; in fact, recent MBTA ridership surveys indicate a high level of customer satisfaction. Other residents may feel powerless about effecting changes. Additionally, some people may have trouble attending night meetings, especially working parents and others who have little time to devote to civic activities.

The city will continue to investigate ways of increasing attendance, including obtaining feedback directly from residents about workable techniques. As the program evolves, the city continues to expand its efforts to publicize the meetings and to attract a wide cross-section of participants.

The initial approach was typical of most city meetings. Notices were sent out to community leaders and elected officials, press releases were placed in local and city-wide newspapers, and notices were sent to the city's public-access cable news program. When possible, fliers were distributed at other neighborhood meetings. Notices were passed out experimentally at neighborhood subway stations but this approach was quickly deemed unsuccessful. (In fact, the meeting for which this technique was used was one of the most poorly attended.)

It was discovered quite early that a major promotional campaign is necessary; there can never be too much publicity. Using a range of techniques is important. Using both standard methods, such as news releases, as well as less traditional ones (e.g., an insert in a local group's mailing) is critical. Even so, there is always some criticism that individuals did not receive enough notice or only heard about the meeting from a neighbor.

Techniques to increase participation currently under consideration include personal phone calls to neighborhood leaders a few days before the workshops. These will have a double purpose: first, to remind people about the meetings and encourage their attendance, and second, to solicit their assistance in recruiting their neighbors and associates for the meeting. Also, telephone calls to local newspapers and other media should also be placed well in advance of the workshops to make sure these outlets are publicizing the workshops.

These efforts should serve to increase attendance substantially. Experience derived from other public participation programs held in the city and the region indicates that a series of personal telephone calls is an effective means of boosting attendance at public meetings.

But, ultimately, the most effective means of increasing participation will be demonstrating the program's success regarding identifiable transit service improvements in response to workshop requests.

In-House Program Management

The transition from consultant to in-house program management has proven extremely successful. Initially, the consulting firm worked with city staff to develop a framework for the program, prepare meeting materials, and produce the final report. City officials opened and closed each public meeting, and the consultants served as facilitators.

To ensure a smooth transition to the program's second year, the city contracted with the same consulting firm to train staff in meeting facilitation skills. BTD staff built upon the first-year framework to produce the second-year program, adding a few refinements and innovations along the way.

The city saves substantial out-of-pocket expenses, and use of staff time has not increased significantly. In the program's first year, staff spent considerable time in meeting with consultants and reviewing materials. Because major decisions about the program format had been worked out in the first year, city staff members were able to devote about the same amount of time in subsequent years to running the program directly.

CONCLUSIONS

TransitTopics has increased public awareness of the city's role in advocating transit improvements. The program has enabled the city to formalize its transit planning efforts in a highly visible forum. Because the TransitTopics program is designed to bridge the gap between the transit-riding public and the MBTA, it complements MBTA planning efforts by creating an ongoing forum for discussing transit operations in Boston.

The tangible results of the program are but one measure of its success. The new bus routes, shelters, and signs are visible reminders of the importance of incorporating public participation into the planning process. Equally important, the program has strengthened the working relationship between the city and the MBTA. By encouraging the MBTA to respond more directly to the concerns of its riders, the program has opened additional lines of communication between the city, the MBTA, and the riding public. MBTA representatives have attended every neighborhood workshop over the past 3 years, and they have expressed their appreciation for the opportunity to listen to citizen comments and concerns in a constructive setting.

Indeed, TransitTopics has helped encourage the MBTA to seek advice directly from its patrons. Not only has the MBTA begun to list participation in TransitTopics as evidence of its own efforts to solicit public input, but the transit authority has recently developed a similar program of its own. In November 1990, the MBTA sponsored a TransitTopics meeting in the city of Somerville. No better evidence of the impact of the TransitTopics program exists.

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Determining Transit Drug Test Accuracy: The Multidrug Case

DAROLD T. BARNUM AND JOHN M. GLEASON

The accuracy of simultaneous testing for two or more drugs of abuse is analyzed. Probability theory and drug-testing accuracy concepts applicable to the testing for multiple drugs are reviewed, these concepts are applied to laboratory proficiency and transportation drug usage data, and accuracy levels are estimated that could occur in transit agency drug testing programs that simultaneously test for five different abused substances. The finding of this analysis is that as the number of drugs tested for increases, the probability that a positive test result is erroneous (the false accusation rate) increases significantly. For example, the false accusation rate when testing for five drugs is about 4 times the false accusation rate when testing for one drug. Therefore, it is suggested that if transit system decision makers wish to obtain certain maximum false accusation rates at their own organizations, they must adapt laboratory sensitivity and specificity rates for the number of drugs actually being tested for.

In U.S. workplaces in general, and in transportation organizations in particular, the testing of job applicants and employees for drugs of abuse continues to play a central role in the battle to eliminate the use of illegal drugs (*1–10*). However, if drug tests are to be an acceptable method of detecting the use of unlawful substances, they must accurately discriminate between those who are using drugs and those who are not. If the tests are not sensitive enough to identify most of those taking drugs, they will neither discourage drug use nor eliminate abusers from the workforce.

More importantly, the tests must be sufficiently specific to classify most nonusers as such. Otherwise, many who are innocent of drug use will be falsely accused. The U.S. systems of justice and of workplace jurisprudence both require that workers must be presumed innocent of infractions until proved guilty with compelling evidence (*11–16*). That is, if drug tests are to be an acceptable way of identifying drug users, they must not classify many people who do not abuse drugs as drug users. That is, there should be a low probability that someone who tests positive is a nonuser, which is referred to as a low false accusation rate.

Recently, Barnum and Gleason (*17,18*) discussed methods by which transit decision makers could set the maximum false accusation rates that would occur in their organizations. Thus, if a decision maker wanted no more than one false positive out of every 1,000 people testing positive, representing a maximum false accusation rate of 0.001, then the methods proposed would permit this goal to be achieved.

This earlier work, consistent with research on testing accuracy (*11,19,20*), developed accuracy estimates based on formulas that implicitly assume that a single test is conducted for the presence or absence of drugs. That is, they assume that each specimen is subjected to one test, and the results of this test will be positive if drugs are present and negative if drugs are absent. In fact, often multiple tests are conducted simultaneously on a specimen, because different substances are used to identify the presence of each drug of interest.

The purpose of this paper is to examine appropriate procedures for dealing with simultaneous tests for multiple drugs, because it is most typical for transit and other transportation modes to test for five illegal substances. That is, the U.S. Department of Transportation (DOT) mandates that most transportation modes simultaneously test for five illegal drugs: amphetamines, marijuana, cocaine, opiates, and phencyclidine (*21*). Although urban transit systems are not now covered by such regulations, most already test simultaneously for the same five drugs. Moreover, legislation has been proposed that would require all to do so by law (*6*).

The procedures discussed incorporate probability concepts that are appropriate under conditions of testing for multiple drugs, and issues are identified that have not been previously considered in the drug testing literature. The procedures may be incorporated into the processes suggested by Barnum and Gleason (*17,18*) to enable transit decision makers to obtain false accusation rates no greater than the level they find acceptable.

UNDERLYING PROBABILITY THEORY

Under proper drug testing protocol, a specimen is first screened for the presence of a drug. If the specimen tests negative for the drug on the screening test, then no more testing is done and it is assumed that the specimen does not contain the drug. However, if the specimen tests positive for the drug on the screen, then a confirmation test is conducted. If the specimen tests negative for the drug on this confirmation test, then it is assumed that the drug is not present; if it tests positive for the drug on this confirmation test, then it is assumed the drug is present. In other words, if a specimen screens negative, it is assumed to contain no drugs. Likewise, if a specimen screens positive but tests negative on the confirmation, it is assumed to contain no drugs. Only if the specimen tests positive on both the screen and confirmation, is it assumed to contain drugs. It is hereinafter assumed that the preceding protocol always has been used to reach test outcomes.

Carefully note that use of the words "one test" refers to one complete test for one drug, which has screening and confirmation components.

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Now, the situation when one test for one drug is being conducted can be reviewed. Excellent detailed descriptions of this process, from differing perspectives, have been provided *(11,19,20,22)*.

When a specimen is tested for a given drug, one of four outcomes must occur. If the drug is not present in the specimen, the specimen may test negative, resulting in a true negative; or it may test positive, resulting in a false positive. Likewise, if the drug is present in the specimen, the specimen may test positive, resulting in a true positive; or it may test negative, resulting in a false negative. These four possible testing outcomes are referred to as individual test outcomes, because they refer to conducting one test of the specimen for one specific drug. (If the specimen is tested for several drugs, as is discussed later in this section, then there will be an individual test outcome for each of the drugs involved. At this point, however, it continues to be assumed that only one drug is being tested for.)

Three measures of drug testing accuracy are used in the health-related professions: sensitivity, specificity, and predictive value. In the following formulas, a positive test result is represented by a + sign, a negative test result is represented by a − sign, a specimen truly containing a drug is represented by a D, and a truly drug-free specimen is represented by an N.

Sensitivity is the probability that a specimen containing a drug will test positive for that drug. Thus, it is the probability of obtaining a true positive. The notation for the probability of a positive test result, given that the specimen contains the drug, is

$$\text{Sensitivity} = P(+|\text{D}). \quad (1)$$

Specificity is the probability that a specimen not containing a drug will test negative for that drug, or the probability of obtaining a true negative. The notation for the probability of a negative test result, given the specimen does not contain the drug, is

$$\text{Specificity} = P(-|\text{N}). \quad (2)$$

Thus, sensitivity measures the ability of the test to correctly report the presence of a drug, whereas specificity measures the ability of the test to correctly report the absence of a drug. Ideally, sensitivity and specificity would both be equal to 1.0, meaning that every drugged specimen tests positive and every nondrugged specimen tests negative.

Another important concept, although not used in studies measuring laboratory proficiency, is the predictive value of a test. For drug tests, the positive predictive value is the probability that the drug is present in a specimen, given that the test yielded a positive result for that drug.

$$\text{Positive predictive value} = P(\text{D}|+) \quad (3)$$

For example, if 90 out of every 100 people testing positive for a drug truly have the drug in their specimens, then the positive predictive value of the test would be 0.90. The probability that people with positive test results truly do not have the drug in their specimens would be 0.10. Therefore, if a drug test has a positive predictive value of X, then the probability is $(1 - X)$ that a person testing positive is free of that drug.

Thus, by maximizing the positive predictive value of a test, the probability is minimized that specimens testing positive are actually drug-free. Herein, this probability that specimens testing positive are drug-free is called the false accusation rate. That is,

$$\begin{aligned}\text{False accusation rate} &= P(\text{N}|+) \\ &= 1 - \text{Positive predictive value} \quad (4)\end{aligned}$$

This concept is key to determining whether a positive result on a drug test provides sufficient evidence of drug usage. If, for example, positive results on a test are known to be untrue in one out of every 10 cases (that is, the false accusation rate = 0.1), then a positive test probably would not be considered sufficient evidence to accuse a person of drug use. More importantly, if one wishes to protect the innocent from false accusation, then it is the positive predictive value of the test (or, analogously, the false accusation rate) that is of prime concern.

All of these concepts implicitly assume that one test for one drug is being conducted (with that test consisting of two parts when a specimen screens positive). That is, the concepts do not account for the situation where tests for several drugs are being conducted simultaneously. The situation can be extended to the case of testing for more than one drug, a topic that to our knowledge has not been addressed in any other publication.

Consider, therefore, a specimen that will be tested for multiple drugs. It either contains none of these drugs or contains one of them. Although it is easy to extend the theory to cases where more than one drug is present in a specimen, the necessary empirical data to make use of this extension are not available. Luckily, the final results would be little affected by the inclusion of more than one drug in a specimen, so the significance of specimens containing several drugs has little practical implication.

Further, only those cases are considered in which an error in the test for any one drug occurs independently of errors in the tests for any of the other drugs. That is, the errors are mutually independent, so the probability of any error is unrelated to the presence of other errors. More formally, if X_i represents a false test result for Drug i, then for n drugs,

$$\begin{aligned}&P(X_1, X_2, X_3, \ldots, X_n) \\ &\quad = P(X_1)P(X_2)P(X_3) \ldots P(X_n) \quad (5)\end{aligned}$$

Thus, systematic errors such as the following are not included in this paper's analysis: cases where conditions causing specimens to test falsely positive for one drug increase the probability of the specimen's testing falsely positive for other drugs, and cases where conditions causing specimens to test falsely negative for one drug increase the probability of the specimens testing falsely negative for other drugs. Such systematic errors are important, and would increase the total error rate to a level higher than that caused by mutually independent errors alone; however, examination of systematic and other sources of error are beyond the scope of this paper.

In the multidrug case, a specimen either will contain no drugs or will contain one of the drugs being tested for. If it contains no drugs, one of two outcomes must occur: (1) it will test negative for all of the drugs, or (2) it will test positive for at least one of the drugs.

If the specimen contains one of the drugs of interest, one of four outcomes must occur: (1) the specimen will test positive for the drug it contains and negative for the other drugs, (2) the specimen will test positive for the drug it contains and positive for at least one of the other drugs, (3) the specimen will test negative for the drug it contains and positive for at least one of the other drugs, or (4) the specimen will test negative for all of the drugs. These results, which are presented in Table 1, are discussed in the following paragraphs.

First, consider the case where no drugs are present in the specimen. If it tests negative for all drugs, then there are true individual negatives for each of the drugs and a true group negative for the specimen. If, however, a drug-free specimen tests positive for at least one drug, then there are true individual negatives for drugs that had negative test results, false individual positives for drugs that had positive test results, and consequently a false group positive for the specimen (because the specimen itself will be declared to be positive when indeed it is not).

Now, consider the case where Drug *i* is present in the specimen, where Drug *i* could be any one of the substances being tested for. If the specimen tests positive for Drug *i* and negative for the others, then there is a true individual positive result and several true individual negative results, leading to a true group positive (and a specimen that is declared positive). If the specimen tests negative for all drugs, then there is a false individual negative result and several true individual negative results, leading to a false group negative (and a specimen that is declared negative incorrectly). These outcomes are fairly easy to interpret; the remaining two possibilities are more difficult.

Again assuming Drug *i* is present, consider the outcome in which the specimen tests positive both for Drug *i* and at least one of the absent drugs. Here, there is one true individual positive and at least one false individual positive, with the remainder of the outcomes being true individual negatives. The specimen would be declared positive; this outcome is classified as a true group positive, because the specimen indeed tests positive for the drug it contains.

Likewise, consider the outcome in which the specimen tests negative for Drug *i* and positive for at least one of the absent drugs. There is one false individual negative and at least one false individual positive, with the remainder of the outcomes being true individual negatives. The specimen would be declared positive. This outcome is classified as a true group positive, because a specimen containing a drug tests positive for a drug, even though it is the wrong drug.

TABLE 1 POSSIBLE OUTCOMES WHEN TESTING A SPECIMEN FOR MULTIPLE DRUGS

TRUE SPECIMEN STATE	POSSIBLE TEST OUTCOMES	SPECIMEN CLASSIFICATION
No Drugs Present	- for all drugs	true group negative
	+ for one or more drugs	false group positive
Drug i Present	+ for drug i, and - for absent drugs	true group positive
	+ for drug i, and + for one or more of absent drugs	true group positive
	- for drug i, and + for one or more of absent drugs	true group positive
	- for all drugs	false group negative

Note that a multiple-test outcome is classified herein as a true group positive whenever the sample tests positive for the drug it contains, regardless of the classification of the other drugs. The multiple outcome is also classified herein as a true group positive whenever the sample tests falsely negative for the drug it contains and falsely positive for one or more of the other drugs. Others may want to modify these two classifications, as they have more to do with what one believes is justice than with probability concepts. As seen later, however, both of these outcomes have such small probabilities of occurrence that their classification makes little practical difference.

Now, for the multiple drug case the individual probabilities can be developed for each of the six possible identified outcomes. As already noted, only mutually independent events are considered.

First, consider the two possible test outcomes for a specimen that contains no drugs. The probability that this specimen will test negative for all drugs is equal to the probability that it tests negative for the first drug, times the probability that it tests negative for the second drug, times the probability that it tests negative for the third drug, and so on.

Recall that the probability that a sample tests negative for a drug it does not contain, or a true negative, is the individual specificity rate. Assume that the individual specificity rates are equal for all of the drugs, that is, $(\text{individual specificity})_1 = (\text{individual specificity})_2 = \ldots = (\text{individual specificity})_n = (\text{individual specificity})_\mu$. The subscripted numbers identify the drug test to which the specificity applies, that is, the individual specificity of the test for Drug 1, the individual specificity of the test for Drug 2, and so on. The subscript μ indicates the mean specificity value for all of the tests. This assumption of equal individual specificities can be written

$$P(-_1|N_1) = P(-_2|N_2) = \ldots = P(-_n|N_n) = P(-|N)_\mu \qquad (6)$$

Of course, specificity may vary by drug. But, because there is no good evidence that individual specificities differ, the insufficient reason approach to decision making suggests that individual specificities be assumed equal.

Now, assume tests are being conducted for n drugs (which means that n tests, one for each drug, must be conducted). The probability that the specimen will test negative for all drugs is the individual specificity rate raised to the nth power, because all individual specificities are identical, and, as elsewhere, errors are assumed to be random and mutually independent. This parameter is group specificity, as opposed to individual specificity that concerns a test for a single drug. Thus,

$$\text{Group Specificity} = [(\text{Individual Specificity})_\mu]^n = [P(-|N)_\mu]^n \qquad (7)$$

Consider a case in which the individual specificity for each drug is 0.999 (the individual false positive rate of each test for a drug is 0.001). This value means that for any one of the drugs, out of every 1,000 samples that do not contain that drug, 999 will test negative for that drug and 1 will test positive for that drug. If five different drugs are being tested for, then the group specificity for those five drugs would be $(0.999)^5 = 0.9950$.

Once the group specificity rate (the probability of all negative test results, given that none of the drugs are truly present) is estimated, this value can be used to identify the probability that this drugless sample will test positive for at least one drug. Of course, if the specimen tests positive for even one of the drugs, it will be declared positive. Because the specimen truly does not contain drugs, this result will be incorrect and hence will be a false positive. Because in this case the false positive applies to a specimen that has been tested for several drugs, this event is called a "group false positive." Recall that the individual false positive probability equals (1 − individual specificity); thus, the group false positive rate equals (1 − group specificity).

For example, recall that in the previous example the group specificity rate for five drugs was 0.9950. The probability that the specimen will test positive for at least one of the five drugs (the group false positive rate) is $(1 - 0.9950) = 0.0050$.

To summarize, the two possible outcomes of a drug test on a truly drug-free specimen have been examined. The specimen can test negative for all of the n drugs being tested for, or it can test positive for one or more of the n drugs. The probability that it will test negative for all of the drugs is the group specificity rate, which is simply the mean individual specificity rate of the drugs being tested for, raised to the nth power. The probability that the specimen will register at least one positive is the group false positive rate, which is 1 minus the group specificity rate. Finally, the probability that a person will falsely test positive for at least one drug increases as the number of drugs being tested for increases.

Now consider the case of tests for multiple drugs, where the specimen indeed contains one of these drugs. One of four outcomes must occur, as presented in Table 1. In order to develop the probabilities of these four outcomes, it is again necessary to start with the individual sensitivity and specificity rates. As before, on the basis of the principle of insufficient reason, the tests for all drugs are assumed to have identical individual sensitivities and identical individual specificities.

First, consider the case in which a total of n drugs are being tested for and the specimen correctly tests positive for the drug it contains and negative for the $n - 1$ drugs that it does not contain. The probability of this occurring equals the individual sensitivity rate for the drug in the specimen, times the individual specificity rate for the remaining drugs raised to the $n - 1$ power. That is, in testing for n drugs, if only Drug i is in the sample, then the probability of a positive test result on Drug i and negative test results for the other drugs is

$$P(+_i, -_j|D_i, N_j) = P(+_i|D_i) * [P(-|N)_\mu]^{n-1} \quad [j = 1, 2, \ldots, n; j \neq i] \qquad (8)$$

where $+_i$ indicates a positive test result on Drug i, D_i represents the presence of Drug i in the specimen, N_j indicates Drug j is not present in the specimen, and $-_j$ indicates a negative test for Drug j. Note that when a probability has a μ for the subscript, then the probability is equal for all drugs, and therefore the particular drug involved is immaterial.

In other words, *Group Sensitivity Part One* = *(Individual Sensitivity)* * *(Individual Specificity)*$^{n-1}$. Because all drugs are assumed to have identical true individual sensitivities and identical true individual specificities, the mean values are simply estimated from empirical laboratory proficiency studies, and do not need to be obtained for each drug. The result is only a partial measure of group sensitivity because, as is described later, other events also contribute to total group sensitivity.

Assume, for example, that a specimen is being tested for five drugs, that their individual sensitivities are all 0.9, and that their individual specificities are all 0.999. Assume also that the specimen contains one of the drugs. The Group Sensitivity Part One, or the probability that the sample will test positive for the drug it contains and negative for the four others, is $(0.9) * (0.999)^4 = 0.8964$.

Second, consider the probability that a specimen containing a drug will test positive for that drug, and will test positive for one or more of the drugs that it does not contain. This probability is the probability that there will be a true positive for the drug that the specimen contains, and at least one false positive for the other drugs. The probability of a true positive for the drug in the specimen will again be the individual sensitivity rate. The probability of at least one false positive for the $n - 1$ remaining drugs will be 1 minus the probability of obtaining all true negatives, that is, [1 − (Individual Specificity)$^{n-1}$]. Thus,

$$P(+_i, + \text{ on one or more others } | D_i, N_j)$$
$$= P(+_i | D_i) * \{1 - [P(- | N)_\mu]^{n-1}\}$$
$$[j = 1, 2, \ldots, n; j \neq i] \quad (9)$$

Because this group contains both true and false positives, it cannot unambiguously be classified into either a true or false category. However, because the objective of the test is to identify drug users, and this event does in fact identify a drug user, it is classified as a true group positive result. Hence, Equation 9, as Equation 8, is a partial measure of group sensitivity. The equation can be written in words as *Group Sensitivity Part Two* = *(Individual Sensitivity)* * [1 − *(Individual Specificity)*$^{n-1}$].

Consider, for example, the case of testing for five drugs with the same individual specificity and sensitivity as before. Then the Group Sensitivity Part Two would be $(0.9) * (1 - 0.999^4) = 0.0036$.

Third, the probability of obtaining a false negative for the drug in the specimen and one or more false positives for the other drugs must be calculated. This probability is the product of two terms: (1 − Individual Sensitivity), and [1 − (Individual Specificity)$^{n-1}$], that is,

$$P(-_i, + \text{ on one or more others } | D_i, N_j)$$
$$= P(-_i | D_i) * \{1 - [P(- | N)_\mu]^{n-1}\}$$
$$[j = 1, 2, \ldots, n; j \neq i] \quad (10)$$

This event includes false negatives, false positives, and potentially one or more true negatives, making its correct classification even more difficult than the previous one. Again assuming that the main purpose of testing is to identify drug users, and because this result does indeed identify drug users, it will be classified as a true group positive. Because it contributes to total group sensitivity, it can be written in words as *Group Sensitivity Part Three* = *(1 − Individual Sensitivity)* * *[1 − (Individual Specificity)*$^{n-1}$].

Using the same assumptions as previously, the probability of this event is $(0.1) * (1 - 0.999^4) = 0.0004$.

The total group sensitivity probability is the sum of the probabilities of these three events occurring, or, in other words, the sum of Group Sensitivity Part One, Part Two, and Part Three. That is,

$$\text{Group Sensitivity} = P(\text{at least one } + | \text{at least one D})$$

Note that this definition is consistent with the meaning of individual sensitivity. Just as individual sensitivity is the probability of a positive test result, given a drug is being used, group sensitivity is the probability of one or more positive test results, given that a drug is being used. For the examples given, the probability of a true group positive, or group sensitivity, is $0.8964 + 0.0036 + 0.0004 = 0.9004$. The formulas for determining group specificity and sensitivity are presented in Table 2.

For completeness, the probability that a specimen with one drug will test negative for all drugs is calculated. This is the probability that there will be a false negative for the drug in question and true negatives for the remaining drugs of interest. The probability of a false negative is one minus the probability of a true positive, or, in other words, one minus the sensitivity rate; and the probability of a true negative is the specificity rate. Thus, the group probability is the probability of a false individual negative, times the probability of a true individual negative raised to the $n - 1$ power, where n drugs are being tested for.

$$P(-_i, -_j | D_i, N_j) = P(-_i | D_i) * [P(- | N)_\mu]^{n-1}$$
$$[j = 1, 2, \ldots, n; j \neq i] \quad (11)$$

Assume, as before, that the individual sensitivity rate is 0.9, that the individual specificity rate is 0.999, that five drugs are being tested for, and that the specimen contains a drug. Then, the probability that the sample will test negative for that drug and negative for the four others is $(0.1) * (0.999)^4 = 0.0996$. Given that a drug is in the specimen, four events could occur, so the total probability of these four events must equal 1.0. When this last probability is added to the previous three (0.0996 + 0.9004), the total is indeed 1.0.

Finally, consider the false accusation rate for the multidrug case. On the basis of the classification scheme used herein, the group false accusation rate is the probability of not being on *any* drug, given one or more positive test results:

$$\text{Group false accusation rate} = P(N_i | \text{at least one } +_i)$$
$$[i = 1, 2, \ldots, n] \quad (12)$$

Thus, the more drugs being tested for, the more chances that one of them will test positive. The exact relationship between

TABLE 2 FORMULAS FOR COMPUTING GROUP SENSITIVITY AND SPECIFICITY

ACCURACY MEASURE	FORMULA
GROUP SPECIFICITY	$(\text{Individual Specificity})^{n}$
GROUP SENSITIVITY	
= Grp Sensitivity I	$(\text{Indiv. Sensitivity})*(\text{Indiv. Specificity})^{n-1}$
+Grp Sensitivity II	$(\text{Indiv. Sensitivity})*[1-(\text{Indiv. Specificity})^{n-1}]$
+Grp Sensitivity III	$[1-(\text{Indiv. Sensitivity})]*[1-(\text{Indiv. Specificity})^{n-1}]$

Note: It is assumed that the tests for all drugs have the same individual specificities, that the tests for all drugs have the same individual sensitivities, and that errors are mutually independent and random.

the number of drugs and the probability of a false positive specimen is illustrated later with transportation data. That is, the theory is used to estimate the potential real-world differences caused by testing for various numbers of drugs.

DRUG ABUSE BY TRANSPORTATION WORKERS

Transportation employee drug use rates vary greatly, depending on such factors as whether the tests are conducted randomly, postaccident, or for cause, and on the basis of such factors as age, gender, the drugs being tested for, and so on. Usually, an organization's positive rate will be lowest for its random tests and highest for its for-cause testing. Rates tend to be much lower for females, workers over 35, and workers in certain regions of the country. Also, because usage rates have declined over the years, more recent estimates tend to be lower than older ones (*23,24*).

In order to identify some appropriate ranges for transit properties in the early 1990s, a few recent rates from transit and other transportation organizations are reported. Averages for the transit industry as a whole, or for any particular transit agency or a subset of its employees, may be higher or lower than the rates presented.

Drug usage rates based on the random testing of Class I railroad employees during 1990 have ranged from 0.3 to 10 percent, with an average of 3 to 4 percent, according to the Federal Railroad Administration (*25*). One urban transit property in an area with very high drug use conducted random testing during January 1990 and found a drug usage rate of 2.7 percent.

Random drug tests of 65,000 current transportation employees during 1990 in a variety of transportation industries by Smith-Kline Beecham Clinical Laboratories showed a positive rate of 3.1 percent. This percentage, according to DOT officials, did not take into account those taking legal prescription drugs or the large variety of legitimate conditions that can result in false positive test results that normally are screened out in medical reviews of the tests. Thus, DOT estimated that the true positive rate was only about half of the 3.1 percent figure, or 1.55 percent (*26*).

Finally, DOT administered 9,941 tests to its own employees, all but 29 random, between 30 September 1989 and 31 March 1990. Of these, 26 were positive, for an overall rate of 0.26 percent (*27*). The drug usage rate of DOT employees is probably lower than this. Given that the 29 nonrandom tests were probably tests for cause, and given that DOT's experience is about half of for-cause tests are positive, about 14 positive results would be expected from the 29 nonrandom tests. This leaves 26 − 14 = 12 positive test results coming from the 9,941 − 29 = 9,912 random tests, for a rate of 12/9,912 = 0.0012, or 0.12 percent.

ACCURACY OF DRUG TESTING

Because of the concerns over whether testing correctly identifies the presence or absence of drugs, a number of laboratory proficiency studies have been conducted. Prepared samples (called "challenges") are sent to laboratories to determine their testing accuracy. When the laboratories cannot distinguish the challenges from normal specimens received for routine testing, the study is a "blind" one. When the laboratories know which specimens are challenges, the study is called "open." Herein, the concern is with how laboratories perform under normal operating conditions, so only blind studies are relevant.

Rather than review all laboratory proficiency studies, estimates from a 1988 article published in the *Journal of the American Medical Association* (JAMA) are used (*28*). The study on which this article was based is considered to be the most relevant to date, because it is recent, it followed a valid research design, and it truly was a blind study.

A more recent study was conducted by the American Association for Clinical Chemistry (*29*). This was a well-conducted study, but it was not a truly blind study. Ten percent of the laboratories in this study knew exactly which client would be submitting the challenges. An additional percentage, the magnitude of which was not identified in the article, knew that one of two clients would be submitting the challenges. Thus, although the laboratories did not know precisely which specimens were challenges, many of the laboratories did know precisely which clients would be submitting the challenges. While the study does indicate what the best laboratories in the country can do when they know they are being tested, it does not necessarily indicate what the laboratories might do under routine day-to-day testing of regular specimens from normal clients. Comprehensive discussions of the applicability to transit of other laboratory proficiency studies has been provided by Barnum and Gleason (*17,18*) and by Allen (*30*). Those concerned with quality assurance issues and false result rates are referred to these three publications.

On the basis of calculations from data presented for the blind phase of the JAMA laboratory proficiency study (*28*), the mean individual false positive rate (number of false positives divided by number of negative challenges) was 0.0016, representing findings on the proportion of drugless specimens where drugs were incorrectly reported to be present. (A "negative challenge" is a specimen that does not contain a drug being tested for by the study.) This statistic is an estimate of $P(+|N)_{\mu}$, and is equivalent to a mean individual specificity level of 99.84 percent. There is no evidence that the presence of a false positive for one drug is related to the presence of false positives for the other drugs.

The mean individual false negative rate (number of false negatives divided by number of positive challenges) was 0.3114 in the JAMA study (*28*). (A "positive challenge" is a specimen that does contain a drug being tested for by the study.) This statistic estimates $P(-|D)_{\mu}$, and reflects a mean individual sensitivity level of 68.86 percent. There is no evidence that the presence of a false negative for one drug is related to the presence of false negatives for other drugs.

Although the 1988 JAMA results (*28*) are used for illustrative purposes, these accuracy levels are not necessarily the averages one would find in the transit industry or at any given property. Accuracy for the industry as a whole or for an individual property may be higher or lower than the JAMA results.

As of July 1991, DOT regulations on drug testing still exclude transit. So, the rigorous uniform standards and National Institute on Drug Abuse (NIDA) laboratory certification procedures that DOT mandates for many transportation modes do not apply to transit agencies, and many properties do not follow such procedures. For example, a 1990 survey of 203 transit agencies from 44 states found that only 70 percent said they always confirmed positive test results, and only 37 percent said that they permitted employees to submit another sample from the original specimen to a laboratory of the employee's choice in the event of a positive test result (*1*). Moreover, not all properties use NIDA-certified laboratories (*18*).

If uniform transit standards eventually were required by DOT, as has been proposed (*6*), most transit properties would be expected to suffer from much lower false positive and false negative rates than were present in the JAMA study. But, even though DOT procedures often would result in extremely high accuracy, both false positives and false negatives undoubtedly still would occur. These could be the result of random and mutually independent laboratory errors, or could be caused by problems in the chain of custody, systematic laboratory errors, or in the misinterpretation of laboratory results by the medical review officer (MRO).

For example, there have been reports of serious divergence between laboratory procedures theoretically required by DOT and actual practice, as discussed in detail in two recent GAO reports (*21,31*). Moreover, there have been a number of false positives reported. In one such case, an MRO discovered the false result, and the following investigation uncovered a number of other incorrect positives that previously had gone undetected (*32*). In another report, the false results were only discovered when a worker, removed from his job several months earlier as the result of the test, filed a grievance through his union. The investigation of the grievance showed that the test was in error (*33*). In this situation also, the uncovering of this one case led to many more that had remained undetected by MROs and had not been challenged by the falsely accused workers. These cases are examples of faulty gas chromatography/mass spectrometry (GC/MS) procedures, and the resulting systematic errors are much easier to discover than the mutually independent laboratory errors that are analyzed here. Although such systematic errors probably represent a very small percentage of the total tests conducted, they show that undetected false positives can and do occur under DOT regulations. Furthermore, although their discussion is beyond the scope of this article, the possibilities for errors beyond the laboratory, caused by factors such as logistic and chain-of-custody problems, are also significant.

Likewise, although DOT wisely included provisions for requiring interpretation of results by MROs in its mandated procedures, and such analyses clearly are very valuable in reducing false positive errors, MRO interpretations are also subject to error (*34*).

In summary, false positives and false negatives undoubtedly occur under current transit industry practices, and undoubtedly would occur even if the uniform industry procedures were mandated by DOT. The actual laboratory error rates are expected to be much lower if the procedures are subject to DOT regulation, but such errors still would occur. The actual error rates in 1990, a period when the transit industry was not regulated by DOT, may be lower or higher than the ones reported by the JAMA study (*28*).

Again, JAMA results are used for illustration only, and the results do not necessarily represent the average for the industry as a whole or the results to be expected at any specific transit property.

Moreover, no matter how high the mutually independent random error rates actually are, false accusation rates can be lowered to acceptable levels by using sufficient reconfirmations of the results with currently available technology.

FALSE ACCUSATION RATES IN TESTING FOR MULTIPLE DRUGS

Consider the impact on the false accusation rate of testing for from 1 to 10 drugs, in which the drug usage rate for the target workforce is 3.0 percent, and in which the individual specificity and individual sensitivity are based on the JAMA (*28*) results, as presented in Table 3.

TABLE 3 GROUP FALSE ACCUSATION RATES BY NUMBER OF DRUGS TESTED

[1] # OF TESTS	[2] STATE	[3] P(State)	[4] Group Sensitivity, & Group False Pos Rate	[5] P(GS)*P(S), & P(GFPR)*P(S)	[6] P(S|+....)
1	Drugs	0.03	0.688600	0.020658	0.930
	No Drugs	0.97	0.001600	0.001552	0.070
	Total	1.00		P(+) = 0.022210	1.000
2	Drugs	0.03	0.689098	0.020673	0.870
	No Drugs	0.97	0.003197	0.003102	0.130
	Total	1.00		P(+) = 0.023774	1.000
3	Drugs	0.03	0.689596	0.020688	0.817
	No Drugs	0.97	0.004792	0.004649	0.183
	Total	1.00		P(+) = 0.025336	1.000
4	Drugs	0.03	0.690092	0.020703	0.770
	No Drugs	0.97	0.006385	0.006193	0.230
	Total	1.00		P(+) = 0.026896	1.000
5	Drugs	0.03	0.690588	0.020718	0.728
	No Drugs	0.97	0.007974	0.007735	0.272
	Total	1.00		P(+) = 0.028453	1.000
6	Drugs	0.03	0.691083	0.020732	0.601
	No Drugs	0.97	0.009562	0.009275	0.309
	Total	1.00		P(+) = 0.030007	1.000
7	Drugs	0.03	0.691578	0.020747	0.657
	No Drugs	0.97	0.011146	0.010812	0.343
	Total	1.00		P(+) = 0.031559	1.000
8	Drugs	0.03	0.692071	0.020762	0.627
	No Drugs	0.97	0.012729	0.012347	0.373
	Total	1.00		P(+) = 0.033109	1.000
9	Drugs	0.03	0.692564	0.020777	0.600
	No Drugs	0.97	0.014308	0.013879	0.400
	Total	1.00		P(+) = 0.034656	1.000
10	Drugs	0.03	0.693056	0.020792	0.574
	No Drugs	0.97	0.15885	0.015409	0.426
	Total	1.00		P(+) = 0.036200	1.000

In the first case in the table, one drug is being tested for. As indicated in Column 2, a urine specimen must be in one of two states: either it contains a drug or it contains no drugs. The specimen has a 0.03 probability of being in the first state, and a 0.97 probability of being in the second, as indicated in Column 3. These probabilities imply that 3.0 percent of the target population uses drugs. The next column, Column 4, identifies the probability of the urine specimen's testing positive for the drug when the drug truly is present (0.6886), and when there truly are no drugs in the sample (0.0016). That is, $P(+|\text{N}) = 0.0016$, and $P(+|\text{D}) = 0.6886$. (The rates in Column 4 are calculated using the formulas in Table 2, and are based on the fact that the false positive rate = 1 − specificity.)

The numbers in Column 5 are the products of the numbers in Columns 3 and 4. That is, for the population being tested, the probability that a person truly is on drugs and tests positive for drugs is 0.020658, whereas the probability that a person truly is not on drugs and tests positive for drugs is 0.001552. The sum of these two probabilities, denoted by $P(+)$ and equal to 0.022210, is the probability of a positive test result.

Dividing each of the numbers in Column 5 by $P(+)$ yields the numbers in Column 6, which are the probabilities of being in the particular states, given a positive test result. Thus, the probability that specimens that test positive will contain a drug is 0.930, meaning the test has a positive predictive value of 93.0 percent. The probability that specimens that test positive will truly contain no drugs is 0.070, meaning the test has a false accusation rate of 7.0 percent. That is, $P(\text{D}|+) = 0.930$, and $P(\text{N}|+) = 0.070$, with the two probabilities totaling 1.0.

The false accusation rates presented are based on illustrative rates for drug usage, individual sensitivity, and individual specificity, and are not necessarily applicable to any particular transit agency. But, all the illustrative rates are ones that could occur in some circumstances. Because of the extremely serious consequences of false accusations of drug use, an employer would be wise to ensure for itself that such estimated rates, or similar rates, do not apply to its case.

In the first case discussed, as previously noted, it is assumed that only one drug is being tested for, similar to the assumptions that led to all of the outcomes discussed by Barnum and Gleason (*17,18*). However, the situation changes when the number of drugs being tested for increases. As indicated in Table 3, as the number of drugs tested for increases, the false accusation rate increases. As seen from Column 6, the one-drug false accusation rate of 7.0 percent increases to 27.2 percent (almost 4 times the one-drug rate) when 5 drugs are tested for, and the rate increases to 42.6 percent (over 6 times the one-drug rate) when tests for 10 drugs are involved.

It is easy to lower the false accusation rates to acceptable levels with automatic multiple confirmation testing, as discussed by Barnum and Gleason (*17,18*), but use of automatic multiple confirmation is not often required. Although employees are sometimes allowed the opportunity to request a second confirmation, the fact that they must request it makes it less likely to occur. The empirical evidence suggests that many falsely accused employees may not request second confirmations (*32,33*). This fact is not too surprising, because many have been told that the tests are foolproof. And, in many cases, the employees themselves have to pay for the second confirmation. Moreover, sometimes more than two confirmations may be necessary, a circumstance that is not typically provided for.

CONCLUSIONS AND IMPLICATIONS OF THE STUDY

Past research in drug testing accuracy (*17,18*) has highlighted the importance of identifying the percentage of those testing positive who are not on drugs, herein called the false accusation rate. However, the impact on this rate of the number of different drugs being tested for has never been addressed. As indicated in the examples, the false accusation rate increases at approximately the same rate as the number of drugs being tested for. That is, the false accusation rate for five drugs is about 4 times the false accusation rate for one drug. Because, in the past, false accusation rates have been based on the implicit assumption that one drug is being tested for, the rates presented have badly understated the true facts.

False accusation rates caused by random and mutually independent errors can be lowered to any desired level by several different means. But, to truly achieve the required rate, it is necessary to take into consideration the number of drugs being tested for.

In order to attain a false accusation rate below some desired maximum when testing for multiple drugs, the following steps must be taken.

1. Determine the maximum false accusation rate that is considered acceptable by the relevant decision makers (including union representatives, if applicable).
2. Estimate the lowest likely rate of drug usage by the workers to be tested.
3. Estimate the highest likely individual false positive and false negative rates for the organization involved.
4. Using the estimated individual false positive and false negative rates, the number of drugs to be tested for, and the pertinent formulas, estimate the group false positive and group false negative rates.
5. Assuming that one test includes a screen and confirmation, and using the expected drug usage rate and the group false positive and false negative rates, estimate the actual false accusation rate.
6. Compare the actual false accusation rate to the maximum acceptable rate. If the latter is higher, the procedure is sufficiently accurate. If the former is higher, the procedure is not sufficiently accurate; either additional confirmations of positive tests must be conducted, individual specificity or sensitivity must be increased, or fewer drugs must be tested for.

This process ensures that false accusations caused by random and mutually independent laboratory errors occur at a lower rate than the desired maximum. It does not address systematic errors or errors occurring outside of the laboratory. These too are important, and could make the total error rate substantially higher, but are beyond the scope of this paper.

In closing, we would like to make a few personal observations. We feel that DOT is working hard to establish rigorous and just testing standards, and the DOT-mandated procedures, once fully implemented, will likely result in substantial improvements in average test accuracy in the transportation modes to which they apply. These error rates can be expected to be substantially lower than those reported by JAMA (*28*).

In the authors' opinion however, there will never be perfect accuracy in drug testing, and there does not need to be. Some individuals will be falsely accused and convicted under all systems of justice. It is not by chance that both the American legal and workplace jurisprudence systems have identified levels of proof that range from preponderance of evidence, to clear and convincing evidence, to proof beyond a reasonable doubt (with the increasingly higher standards being applied as punishments become more severe). But, even for the most severe punishments, absolutely perfect proof is not required, and it is expected that there will be cases of error. The critical question is not how to avoid false accusations, which is impossible unless everyone is assumed innocent, but how to be sure that the errors that do occur will be at an acceptably low rate. One good way to achieve desired error rates is to control them by methods such as those identified in this paper.

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DISCUSSION

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The authors' conclusion that the false accusation rate (FAR) is an appropriate measure of drug testing accuracy is misleading. According to the authors' definition, the FAR is a function of the sensitivity and specificity of drug testing and the prevalence of drug use in the population being tested. Drug use prevalence does not affect laboratory accuracy. The application of the author's statistical methodologies to workplace drug testing is also based on experience from clinical diagnostic testing, which is not necessarily germane to analytical toxicology. Furthermore, the conclusions are based on an assumption that random testing errors occur at an equal rate for any combination of drugs being tested for. This assumption does not consider the procedures available to control for random errors in an independent serial testing protocol.

The procedures required in National Institute on Drug Abuse (NIDA) certified laboratories control for random laboratory error, in part, by the independent administration of two types of testing methodologies [immunoassay and gas chromatography/mass spectrometry (GC/MS)]. Specimens that are positive on the immunoassay are then tested using a separate aliquot subjected to GC/MS confirmation; it is not simply a continuation of the testing process using the same aliquot. Thus, the assumption that random laboratory error can be determined on the basis of dependent factors in the testing process is unsubstantiated. The authors use the insufficient reason approach to make their assumption that the individual specificity, sensitivity, and predictive value for each drug tested for are equal. In fact, sensitivity, specificity, and predictive values are very different for the various classes of drugs.

Although the authors emphasize that their many assumptions may not apply to DOT-mandated testing conducted in NIDA-certified laboratories, they claim that their conclusions and recommendations are universally applicable to drug testing in the workplace. This progression is questionable. DOT does not assert that random laboratory errors are impossible. However, current procedures and NIDA laboratory protocols that respond to different sensitivity and specificity rates for individual drugs through controlled cutoff levels; independent serial testing procedures; and internal laboratory controls, standards, and calibration greatly minimize random laboratory error.

The authors discuss false positive rates, FAR values, and false conviction rates (the latter, undefined). False positive rates are based on laboratory findings (i.e., identifying a drug or drug metabolite when it is in fact not present) and are not based on whether or not the individual illicitly used a controlled substance. When a specimen contains an identified drug or metabolite, the determination of whether that metabolite got there as a result of prescribed medication or illicit drug use has no relationship to its being a false positive.

Blind proficiency data from DOT-mandated testing have yet to produce a false positive. There have been reported false negatives. The authors' observation of the lack of published data on the blind proficiency testing program for DOT-mandated testing is valid. The blind proficiency program is not a one-shot research design. It is a programmatic requirement and the only source of information for the results is from the individual employers participating in the ongoing proficiency testing program. There is no evidence to support that employers are withholding information concerning false positive events in the blind proficiency programs. The employer-supplied blind proficiency specimens, the NIDA proficiency testing program, and the laboratories' own internal open and blind proficiency testing programs combine to provide a comprehensive quality control program that monitors laboratory accuracy (and random laboratory error) on an ongoing basis.

Because of the factors discussed by the authors and the findings in the *Journal of the American Medical Association* (JAMA) articles cited by the authors, DOT and NIDA adopted the rigorous standards and procedures that currently exist in NIDA-certified laboratories. The GAO reports cited by the authors did not explore the issue of laboratory accuracy or random laboratory error. GAO's concern was the implementation of workplace drug testing policies and programs. The analytic framework used in the authors' paper is somewhat inappropriate for viewing the accuracy of a workplace drug testing program. It is more appropriate for use in medical diagnostic work. In medical diagnosis, the positive predictive value (PPV) has an individualistic interpretation (i.e., the probability that an individual has a disease given that they test positive on whatever indicative test is performed). In a medical diagnosis scenario, the prevalence of the disease plays a critical role in interpreting a test result. In assessing drug testing programs, the prevalence of drug use in the population should not necessarily play a role in the accuracy of the testing methodology. This should be done on the basis of the test (analytic process) itself (i.e., the false positive rate or false negative rate).

The FAR is given as the number of false positives divided by the number testing positive. The number testing positive is influenced by the prevalence rate. A larger prevalence rate should, therefore, have a smaller FAR than a program with a small prevalence rate—even though both may have the same number of false positives. The FAR does not therefore present an equitable evaluation across the universe of drug testing programs. Drug use prevalence is thus irrelevant to drug testing methodology accuracy.

False positive rates are derived from laboratory accuracy and reliability and are not affected by drug prevalence or incidence rates. The protection of the individual employee is paramount in any workplace drug testing program and that is why DOT believes that the rigorous procedures and standards imposed on NIDA-certified drug testing laboratories are essential. Hopefully, the transit industry, though not currently required to adopt DOT and NIDA guidelines, will pursue the use of such standards in their nonregulated programs.

Authors' Closure

Dr. Smith's remarks almost entirely concern DOT and NIDA procedures, yet, as she admits, these procedures currently are inapplicable to transit. Moreover, she does not address the topic of our paper: the relationship between the number of drugs tested for and the percentage of people who are falsely accused of drug use. That is, even if everything Dr. Smith said were true, it would have no bearing on transit and no bearing on the accuracy of testing for multiple drugs. Further, her discussion contains many incorrect and misleading statements. Unfortunately, treatment of all these issues is precluded by the space limit placed on our response.

The objective of our paper was to exhibit the impact that testing for several drugs, rather than for one drug, has on the accuracy of the drug-testing process. Because of the way in which sensitivity and specificity have been calculated heretofore, all prior drug testing analyses have implicitly assumed that a specimen was being tested for only one drug. That is, past analyses have failed to take into account the simple laws of probability that prevail in cases in which specimens are tested for several drugs. Our concern was to point out the probabilistic implications of the multiple-drug case, in order that potential problems could be dealt with in the design of accurate testing processes. Our conclusion was that an increase in the number of drugs tested for in a specimen also increases the probability that a given specimen will be falsely classified as positive. Dr. Smith never addresses this conclusion or the discussion justifying it.

Dr. Smith states "DOT does not assert that random laboratory errors are impossible. However, current procedures and NIDA laboratory protocols . . . greatly minimize random laboratory error." Thus, the discussant acknowledges that random errors can occur. It is notable, however, that DOT's blind proficiency sampling procedure has not been powerful enough to discover any false positives, although false positives have been reported by others (*1*,p.8).

We agree with Dr. Smith's statement that drug use prevalence does not affect laboratory accuracy—however, we never claimed it did. Our point, in the current paper and in previous papers (*2,3*), is that sensitivity and specificity rates should not be viewed in the absolute. Rather, the impact of sensitivity and specificity must be viewed from the perspective of their interaction with drug use prevalence rates, as determined by a Bayesian analysis. Clearly, as indicated by the results provided in our previous paper (*2*), which deals with the Bayesian concepts, the false accusation rates differ depending on prevalence of drug use. That is, for given sensitivity and specificity levels, the false accusation rate will be higher in groups with low drug use prevalence than in high-prevalence groups.

By focusing on laboratory error rates, Dr. Smith misses the critical point. Laboratory accuracy is only a means to an end, the end being to avoid false accusations. For example, the fact that a laboratory reports only one false positive out of every million drug-free samples is completely irrelevant if this still results in 9 out of every 10 positives being false accusations. A given laboratory accuracy level may result in very high or very low false accusation rates. It is important to start with acceptable false accusation rates and work backwards to the laboratory accuracy levels required for each target group. Our effort has been to suggest procedures to identify the potential impact of random errors on various target groups, and to suggest processes to deal with these potential errors. We appreciate Dr. Smith's discussion, and the opportunity it has given us to reemphasize these issues.

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Tualatin Park-and-Ride Lot Program Evaluation

CAROL AMBRUSO

In September 1988, Tri-Met opened a new park-and-ride lot near I-5 on the southwest side of Tri-Met's service district. The lot was built to serve residents of the suburban community of Tualatin. It provides 204 parking spaces and a covered waiting area. A campaign was undertaken to promote the new lot and the Line 96 express bus, which provides nonstop, 20-min service from the park-and-ride lot to downtown Portland. Research undertaken to assess the effectiveness of the promotion included counting the number of cars in the park-and-ride lot, the number of passengers who boarded Line 96 at the park-and-ride lot, and the total passengers on board Line 96. Surveys were conducted of passengers on board Line 96 and persons who received a direct mail promotional packet. Major conclusions of the study were as follows: (a) Use of the lot increased steadily from September 19, 1988 (the day the lot opened), until it reached capacity in mid-January. (b) Ridership on Line 96 increased by 283 percent between September 5, 1988, and January 24, 1989.

On September 19, 1988, Tri-Met opened a new park-and-ride lot at the junction of I-5 and Lower Boones Ferry Road. The lot was built to serve residents of the suburban community of Tualatin located on the southwest side of Tri-Met's service district. Figure 1 shows the location of the park-and-ride lot in relation to the Line 96 route and the downtown Portland bus mall. This lot provides 204 parking spaces and a covered waiting area for Tualatin area residents. It effectively replaced the 80-space parking lot on Seneca Street in the city of Tualatin. Just before the park-and-ride lot opened (on September 6), three inbound and two outbound trips were added to the Line 96 Tualatin-Wilsonville bus route. Also, the number of articulated buses on this route was increased from two to five.

In addition to promoting the new park-and-ride lot, a decision was made to also promote Line 96 as express service. From the park-and-ride lot, Line 96 provides nonstop, 20-min service to downtown Portland on weekdays during peak hours. Although service from Tualatin to downtown Portland has always been nonstop, this service heretofore had not been promoted as express service. Several promotional activities took place before and after the park-and-ride lot opened, as follows:

1. August 10, 1988. Large information signs were placed at the park-and-ride lot construction site. These signs informed the public when the lot would open and what type of service Tri-Met would provide from the lot.
2. August 18, 1988. Posters promoting the Line 96 express service and the Line 38 Boones Ferry service were sent to all downtown Portland employers of 50 or more persons. Posters were also sent to employers in Tualatin and Wilsonville to promote service to reverse commuters (persons not traveling in the peak direction).
3. August 31 and September 15, 1988. A representative from Tri-Met's rideshare program conducted on-site pro-

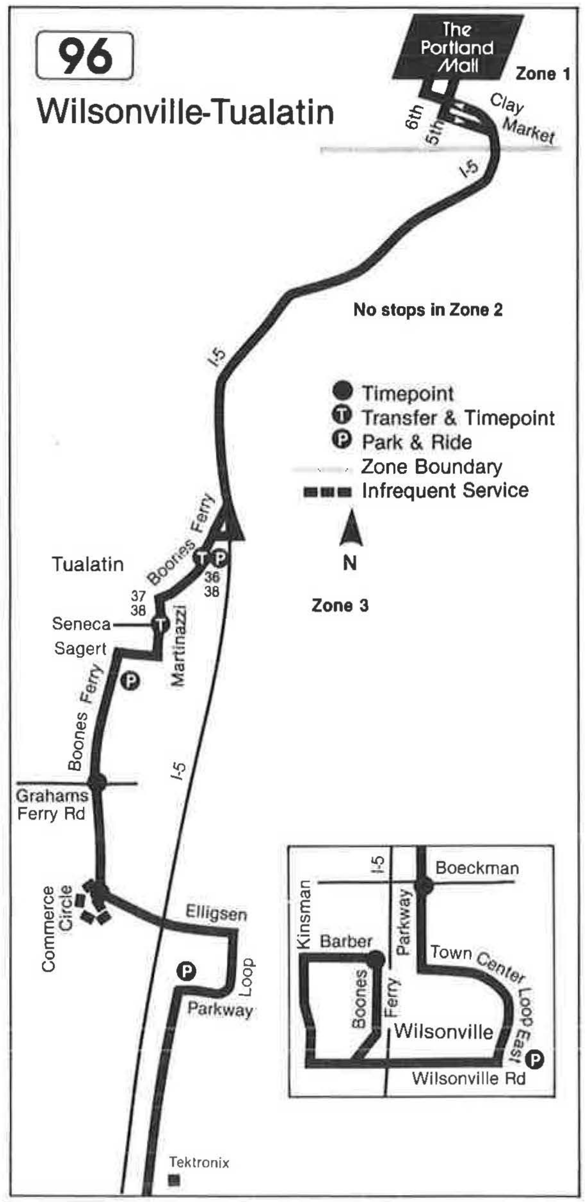

FIGURE 1 Line 96 express route map.

Tri-County Metropolitan Transportation District of Oregon, Public Services Division, 4012 S.E. 17th Avenue, Portland, Oreg. 97202.

motions at the South Center Business Park in Tualatin. Individual trip plans were developed for approximately 150 persons.

4. September 8, 1988. Pathfinder signs directing commuters to the park-and-ride lot were strategically placed in the Tualatin and Lake Oswego areas.

5. September 1988. Individual, handwritten letters and a day pass were sent to 35 persons who had inquired about the new park-and-ride lot while it was under construction.

6. September 1988. Signs were posted at the Seneca Street park-and-ride lot advising patrons the lot would no longer be served and directing them to park at the new park-and-ride lot beginning September 19.

7. September 19, 1988. The park-and-ride lot was officially opened with a welcoming committee from Tri-Met serving coffee and doughnuts.

8. October 14, 1988. A direct-mail packet was sent to 9,549 residents in the Tualatin-Wilsonville area. The packet contained a letter informing residents about the new park-and-ride lot and the express service to downtown Portland, emphasizing the benefits to the commuter of riding. The packet also contained a map of the bus route, a Line 96 schedule, a ticket for five free days of riding on Tri-Met if the first trip of each day began on Line 96, and an offer of 25 percent off any book purchased at Book Merchants just for using all five free days of riding.

9. October 16, 1988. A newspaper advertisement regarding the Tualatin park-and-ride lot and the Line 96 express service was placed in the local paper, the River City Press. At the bottom of the advertisement was a coupon readers could return for the direct-mail packet described earlier.

10. October, 1988. A short news article regarding the new park-and-ride lot was placed in the *Commuter*. This paper is delivered to Salem-bound commuters who were members of Tri-Met's carpool data base, government offices in Salem, the state library, and Salem City Hall.

11. Late October 1988. A letter promoting the park-and-ride lot as a carpool staging area was sent to all commuters from Portland to Salem who were listed in the Tri-Met carpool data base.

RESEARCH METHODOLOGY

The objectives of the promotion were to increase use of both the Tualatin park-and-ride lot and the Line 96 express service.

The research undertaken to assess the effectiveness of the promotion was multifaceted. Individual components of the research were as follows:

1. The number of cars parked at the Tualatin park-and-ride lot were counted from the week after the lot opened through the second week of January.
2. The number of passengers boarding and alighting at the Tualatin park-and-ride lot and the number of passengers aboard the bus when it left the lot were counted periodically between September 5, 1988, and January 26, 1989.
3. The actual number of newspaper advertisement coupons and tickets redeemed for a discounted book were recorded.
4. A questionnaire was distributed on board Line 96 to determine when passengers began riding Line 96 and why.
5. A survey was sent to the 9,549 persons who were mailed the direct-mail packet.

The results of each research component and conclusions and recommendations regarding the effectiveness of the direct-mail promotion are described in the following sections.

RESULTS OF RESEARCH

Park-and-Ride Lot Counts

The number of cars using the Tualatin park-and-ride lot increased steadily after the lot opened on September 19, 1988. By the beginning of 1989, the lot was consistently at or near capacity. Initially, many of the cars may have belonged to persons moving from the 80-space Seneca Street lot. However, it is clear that patronage of the Tualatin park-and-ride lot increased well beyond the number who previously used the Seneca Street lot. Although no hard data exists, in addition to those who park and ride Line 96, Tri-Met has learned that several groups are using the lot as a staging area for carpools.

Figure 2 shows the average daily use of the Tualatin park-and-ride lot on weekdays from September 26, 1988, through January 20, 1989. The sharp drop shown in Week 16 is because only 1 day was counted that week—December 27. In all likelihood, the low count that day was caused by the holiday season when many people take time off work.

Load Counts at Tualatin Park-and-Ride Lot

Load counts taken on September 5, 1988 (before the Tualatin park-and-ride lot opened), indicated that the number of persons riding into downtown Portland between 6:20 and 8:00 a.m. on the Line 96 Tualatin-Wilsonville express was 126. As shown in Figure 3, this number increased steadily since the lot opened. Load counts on January 24, 1989, indicated that the number of inbound passengers on the Tualatin-Wilsonville bus was 356, an increase of 283 percent.

The number of passengers boarding at the park-and-ride lot during morning peak hours was also recorded. When the lot opened on September 19, 1988, only 44 persons boarded the Line 96 bus at the new park-and-ride lot. By September 27, this number had more than doubled, and on January 24, 1989, 224 passengers boarded inbound Line 96 buses between 6:20 and 8:00 a.m. at the park-and-ride lot.

The number of persons traveling from downtown Portland to Tualatin in the morning hours has remained fairly constant. On October 11, 1988, 49 passengers rode outbound Line 96 buses in the morning. This number increased to 68 on November 30, 1988, and then decreased to 52 on January 24, 1989.

Newspaper Coupon and Ticket Redemption

On October 16, 1988, an advertisement was placed in the River City Press, a local newspaper. At the bottom of this advertisement was a coupon that could be redeemed for the

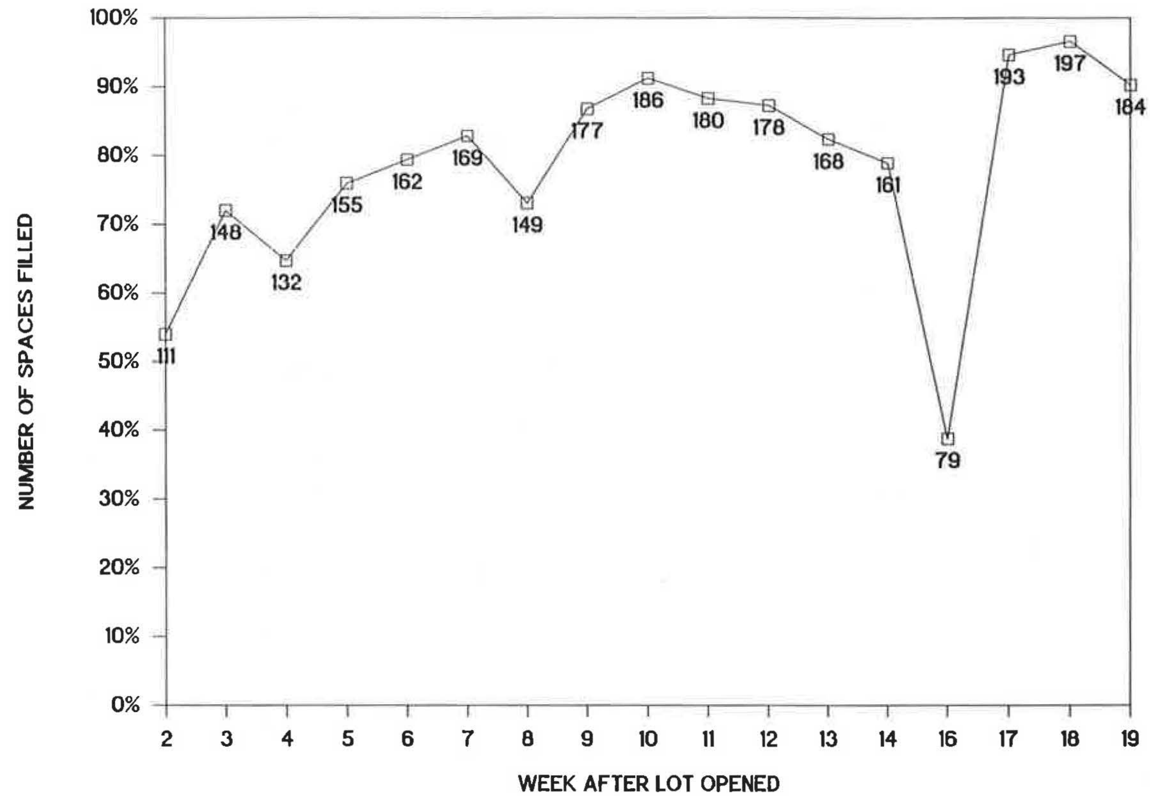

FIGURE 2 Tualatin park-and-ride lot counts.

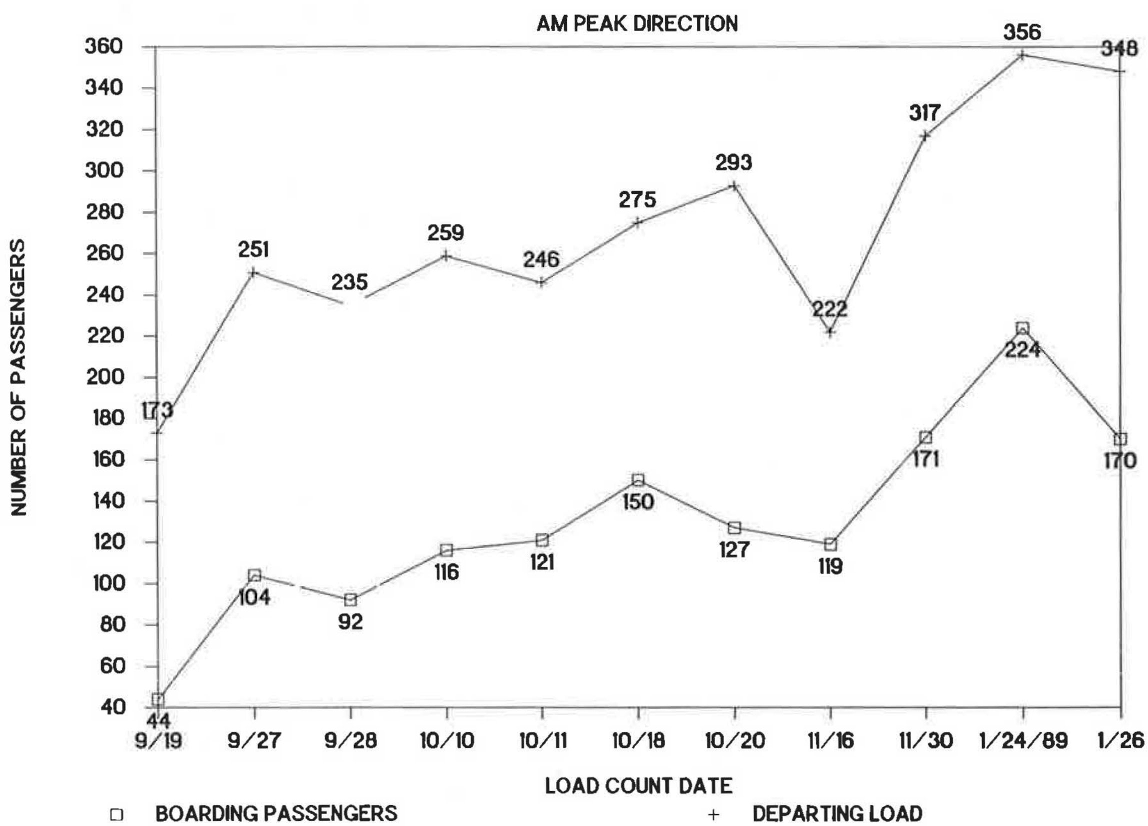

FIGURE 3 Load counts at Tualatin park-and-ride lot.

direct-mail packet mentioned earlier. Overall, 67 newspaper coupons were redeemed.

On October 14, 1988, the direct-mail packet was sent to 9,549 persons in the Tualatin-Wilsonville area. The packet contained a letter informing residents of the new park-and-ride lot and the Line 96 express service to downtown Portland. The packet also contained a map of the bus route, a Line 96 schedule, and a ticket for five free days of riding if the first trip of the day was on Line 96. When all 5 days of riding had been used, the passenger could redeem the ticket for 25 percent off any book purchased at Book Merchants.

Including the persons who redeemed the newspaper advertisement coupons, a total of 9,616 tickets for five free days of riding were sent out. Only 31 were redeemed for a discount book.

Line 96 On-Board Survey

On December 7, 1988, Dan Gargan and Associates conducted a survey of passengers on morning trips on Line 96. In all, 286 surveys were completed, representing 76 percent of the morning passengers that day. The maximum margin of error for a survey of this size is ±6 percent at the 95 percent confidence level.

More than 40 percent of respondents began riding Line 96 after the Tualatin park-and-ride lot opened. New passengers said they were prompted to try Tri-Met to save money on parking (28 percent), to avoid driving hassles (27 percent), or because they did not have a car available (17 percent). A handful of persons mentioned getting a free ticket in the mail or word of mouth as their initial reason for riding.

Respondents were given a list of ways in which they may have heard about the Tualatin park-and-ride lot and express service on Line 96. The sources of information that respondents most often remembered are presented in Table 1.

More than half (59 percent) of the new riders boarded the bus at the Tualatin park-and-ride lot. By comparison, 38 percent of all riders boarded at the lot; the remainder boarded at other points along the route.

The majority (59 percent) of new passengers drove to the bus line (including 46 percent who drove to the new park-and-ride lot), 16 walked to a bus stop, 14 percent were dropped off by car, and 11 percent transferred from a bus or MAX train. Among all passengers, 46 percent drove to the bus line, 27 percent walked, 11 percent were dropped off by car, and 14 percent transferred from another Tri-Met vehicle.

The majority of respondents who transferred from a bus or MAX train (83 percent) were reverse commuters—that is, persons who were traveling outbound in the morning on Line 96 from downtown Portland.

More than 90 percent of all passengers were riding the bus to work. An additional 5 percent were going to school. There was no difference in trip purpose between new passengers and those who started riding before the park-and-ride lot opened. Although outbound passengers made trips primarily either to work or home, inbound passengers also made trips to school, to see the doctor, and for other purposes.

The most popular method of fare payment was a monthly pass. This method was favored by 45 percent of all riders and 42 percent of new riders. One-third of the riders in both groups use tickets and 19 percent of all riders pay with cash, compared with 22 percent of new riders.

TABLE 1 ON-BOARD SURVEY SOURCES OF INFORMATION

Do you recall hearing about the Tualatin Park & Ride lot and express service on the Line 96 Wilsonville-Tualatin from...

	New Riders (N=118)	All Respondents (N=286)
Driving by the Park & Ride lot	77%	71%
A friend or co-worker	35	28
A packet in the mail	28	25
A sign at the old Seneca St Park & Ride	3	18
An ad in the local newspaper	13	16
Your bus driver	4	13
A personalized letter from Tri-Met	10	11
A poster at work	3	3
An article or ad in the Commuter	0	2
A Tri-Met representative at work	2	1
Other	12	11

Outbound passengers were substantially more likely to pay with cash and less likely to use tickets than inbound passengers. Pass usage among members of these two groups was not substantially different. The disparity between groups relating to the use of cash versus tickets may be caused by the substantially lower incomes of outbound passengers.

Demographic characteristics for respondents to the Line 96 on-board survey are presented in Table 2.

More than half (51 percent) of all respondents said they were very satisfied with service on Line 96, and over one-third (37 percent) were somewhat satisfied. New riders expressed a slightly higher level of satisfaction than did the total sample. When asked why they were satisfied or dissatisfied with the service, more than one-quarter said the service was fast, and 21 percent said it was convenient. Problems mentioned included late buses (20 percent), not enough runs (18 percent), and overcrowding (11 percent).

When asked how service on Line 96 could be improved, 57 percent of those who responded to the question suggested adding runs, 24 percent wanted larger buses, and 11 percent wanted on-time performance. One respondent asked for coffee.

Although requests for larger buses were to alleviate perceived overcrowding, requests for more runs related to a need for midday, evening, and weekend service that Tri-Met does not currently provide.

Direct Mail Survey

Response to Direct Mail Packet

On December 2, 1988, Tri-Met sent a mail-back survey to the 9,549 persons who were sent a direct-mail packet. A total of 1,149 completed surveys were returned, yielding a response rate of 12 percent. The maximum margin of error for a survey of this size is ±3 percent at the 95 percent confidence level.

Three out of four survey respondents (75 percent) remembered receiving the direct mail packet. The packet seems to have been fairly appealing to respondents. Among those who remembered getting the packet, two-thirds (67 percent) said they read all of it, and an additional 10 percent reported reading at least half. Only 3 percent said they did not read any of the packet.

Respondents who received the packet said the schedule was the most useful information (37 percent), followed by the free ticket (30 percent) and the informational letter (26 percent).

Free Ticket Use

When asked who, if anyone, used the free ticket, 72 percent said it was not used. Not surprisingly, the majority of these respondents were nonriders (86 percent). An additional 10

TABLE 2 ON-BOARD SURVEY DEMOGRAPHIC CHARACTERISTICS OF LINE 96 PASSENGERS

Characteristic	All Riders (N=286)	New Riders (N=118)	Inbound Riders (N=234)	Outbound Riders (N=52)
AGE				
16 and Under	0.8%	0.0%	0.9%	0.0%
17 to 24	10.9	15.5	11.4	8.5
25 to 34	32.9	39.1	31.3	40.4
35 to 44	32.6	28.2	33.6	27.7
45 to 54	17.4	14.5	16.6	21.3
55 to 64	4.3	0.9	4.7	2.1
65 and Over	1.2	1.8	1.4	0.0
INCOME				
Under $10,000	7.3%	7.8%	2.7%	26.1%
$10,000 to $19,999	20.1	21.6	15.4	39.1
$20,000 to $29,999	17.5	11.8	17.6	17.4
$30,000 to $39,999	23.5	25.5	26.6	10.9
$40,000 to $49,999	14.1	11.8	16.5	4.3
$50,000 or More	17.5	21.6	21.3	2.2

* Percentages may not add to 100 due to rounding.

percent were persons whose riding frequency has remained constant. A closer look at this smaller group shows that more than half ride Tri-Met at least 30 times per month. In all likelihood, these respondents did not use the free ticket because they had purchased a monthly pass.

In addition to the tickets that were not used, nearly one respondent in five (19 percent) reported using the free ticket personally, 6 percent gave it away, and 3 percent were used by someone in the respondent's family. Among those who used the tickets personally, 22 percent were nonriders before the promotion who reported riding two or more times per month after the promotion. More than one-third of these former nonriders (15 persons) changed their riding frequency from 0 transit trips per month to 30 or more.

Almost all respondents who personally used the free pass commute to work or school at least 4 days per week. When asked how many free days of riding they used, 68 percent reported using all 5 days. Eight percent used 4 days, 7 percent used 3 days, 9 percent used 2 days, and 8 percent used 1 day.

Among respondents who used the free ticket, 20 percent (30 persons) reported redeeming the ticket for a discount book coupon. Tri-Met actually received 31 tickets. The closeness of these numbers indicates that almost all of the people who received the free book also filled out and returned a survey. This finding is supported by the marketing theory that persons are more likely to complete and return a form if they are rewarded with something they perceive as valuable. Moreover, research shows that certain types of people are generally more likely to respond to a survey or other research format than other types of people.

The direct mail survey provides some interesting results related to respondents' commute mode before and after the promotion. Table 3 presents the riding frequencies and commute modes both of free ticket users and all survey respondents before and after the promotion.

Although Table 3 indicates trends in commute mode and riding frequency, it is incomplete in that it only presents overall totals, not individual fluctuations. For example, under "All Respondents," the table indicates little change in overall riding frequency from before the promotion to after the promotion. When looking at individual respondents, however, results indicate that 10 percent of those who did not ride Tri-

TABLE 3 DIRECT-MAIL SURVEY RIDING FREQUENCY AND COMMUTE MODE BEFORE AND AFTER PROMOTION

Characteristic	FREE TICKET USERS (N=160) Before Promotion	FREE TICKET USERS (N=160) After Promotion	ALL RESPONDENTS (N=1,149) Before Promotion	ALL RESPONDENTS (N=1,149) After Promotion
COMMUTER STATUS				
Commuter	--	96%	--	93%
Non-Commuter	--	4	--	7
COMMUTE MODE				
Drive Alone	30%	21%	70%	70%
Carpool	19	15	11	10
Tri-Met	48	62	15	17
Other	3	3	5	4
RIDING FREQUENCY (Trips per Month)				
0- 1	39%	21%	79%	78%
2- 6	6	6	5	4
7-12	5	11	2	4
13-29	17	17	4	4
30-99	33	45	10	11

-- Not Available.

* Percentages may not add to 100 due to rounding.

Met before the promotion made two or more transit trips following the promotion and 2 percent of all survey respondents increased their riding frequency.

During the same time period, almost 4 percent of survey respondents decreased their riding frequency. The greatest number of these were persons in the light rider category (2 to 6 trips per month). Members of this group may have been persons who used transit once or twice in September because their regular transportation method was not available (i.e., their car broke down). Other explanations for decreased riding frequency in December include normal attrition and an increased perception of the need for a car to do errands and holiday shopping.

Tualatin Park-and-Ride Lot Use

Increasing ridership on the Line 96 bus was only one objective of the promotion. The second objective was to promote use of the Tualatin park-and-ride lot. When asked how they usually get to the bus or MAX line, 30 percent of those who ride Tri-Met said they drive to the Tualatin park-and-ride lot, 34 percent walk to a bus stop, 16 percent drive to a bus stop, 7 percent drive to another park-and-ride lot, 7 percent are dropped at a bus stop, and 6 percent reach Tri-Met vehicles by other means.

The level of transfer activity indicated by the survey is low in comparison with the total system. One reason for this is because the survey was sent to persons in the Tualatin area who generally commute in to Portland to work and may then transfer to another bus or MAX. The survey was not sent to persons in Portland who may transfer to Line 96 on their way to jobs in Tualatin.

The number of persons who currently drive to the Tualatin park-and-ride lot includes nearly three-quarters of those who previously parked at the Seneca Street park-and-ride and two-thirds of all new riders. Almost three-quarters of respondents who used the free ticket said they began or ended their trips at the Tualatin park-and-ride lot.

Sources of Information

Respondents were given a list of ways in which they may have heard about the Tualatin park-and-ride lot and express service on Line 96. The sources of information that the respondents remembered is presented in Table 4. These sources are listed in descending order by the percentage of all respondents who recalled that particular source.

Personalized letters were sent to only 35 persons who had inquired about the park-and-ride lot while it was under construction. Comments on the survey form indicated that respondents probably believed this category referred to the informational letter in the packet. This belief accounts for the high level of recall of the personalized letter.

In addition to the sources presented in Table 4, respondents were asked if they had seen a Tri-Met advertisement in the local paper in October. In all, 21 percent of survey respondents said they remembered seeing the October 16 advertisement that appeared in the *River City Press*. The advertisement did not generate a large response. Of those who remembered seeing the advertisement, only 7 percent (15 persons) reported sending in the order form at the bottom. Tri-Met actually received 67 order forms, including those received from persons not sent the direct mail packet.

Satisfaction with Tri-Met Service

Nearly one-third of all survey respondents said they were very satisfied with Tri-Met service; an additional 43 percent were somewhat satisfied. When asked why they were or were not satisfied, 18 percent cited a need for more service—partic-

TABLE 4 DIRECT-MAIL SURVEY SOURCES OF INFORMATION

Q. Do you recall hearing about the Tualatin Park & Ride lot and express service on the Line 96 Wilsonville-Tualatin from...

Information Source	New Riders (N=46)	All Riders (N=243)	All Respondents (N=1,149)
Driving by the Park & Ride lot	70%	67%	75%
A personalized letter from Tri-Met	51	44	38
A friend or co-worker	23	20	12
A sign at the old Park & Ride lot	0	10	8
A Tri-Met Representative at work	8	5	3
Your bus driver	3	10	3
An article or ad in the Commuter	0	3	2
A poster at work	0	3	2
Other	14	12	7

ularly midday, evenings after 7 p.m., and weekends. Nine percent (9 percent) said there is no service to their destination, 8 percent said Tri-Met provides a needed service, and 5 percent said they like the express service.

New riders were considerably more positive in their assessment of Tri-Met service. More than half (51 percent) of all new riders said they were very satisfied with Tri-Met service; 39 percent were somewhat satisfied. When asked why they were satisfied or dissatisfied, 32 percent said there was a need for more service, 13 percent said buses are reliable, ^ percent mentioned the service was convenient, 6 percent said buses are late, and 5 percent said thev like the express service.

Demographic Characteristics of Survey Respondents

Table 5 presents the demographic characteristics of all direct mail survey respondents, all riders, new riders only, and free ticket users.

CONCLUSIONS

The Tualatin park-and-ride lot promotion was one of the mos comprehensive promotions ever done at Tri-Met and the effort appears to have paid off.

Use of the new lot increased steadily from September 19, 1988 (the day the lot opened), until it reached capacity in mid-January.

Ridership on Line 96 increased substantially. Not only did use of the park-and-ride lot increase, but according to the on-board survey, the direct mail survey, and load counts at the Tualatin park-and-ride lot, ridership on Line 96 increased substantially. Load counts show an increase in ridership of 283 percent between September 5, 1988, and January 24, 1989.

The pervasiveness of information contributed greatly to the success of the new lot and express service. For sources from which respondents both to the one-board survey and to the direct mail survey got their information about the park-and-ride lot, their number and location appeared to vary. For example, nearly half of the new riders got their information from a single source. However, when asked what that source was, 48 percent said driving by the lot, 23 percent mentioned a letter from Tri-Met, 14 percent heard from a friend or co-worker, 10 percent heard from a Tri-Met representative at work, and 5 percent heard about the lot from a source not listed.

The information sources that reached the greatest number of people were the large information signs placed at the park-and-ride lot during construction, the direct mail packets, and a Tri-Met representative at the South Center Business Park in Tualatin.

For persons who already rode the bus, other important sources of information were the bus driver and signs placed at the old Seneca Street park-and-ride lot.

Free tickets provided necessary incentive for trying the bus. When respondents to the on-board survey who were new bus riders were asked why they initially started riding the bus, most mentioned saving money on parking, avoiding driving hassles, or lack of an available car. Few mentioned getting a free ticket in the mail. The direct mail survey indicated, however, that among the persons who used the free ticket personally, 22 percent were nonriders before the promotion. This finding indicates that although respondents may believe they

TABLE 5 DIRECT-MAIL SURVEY DEMOGRAPHIC CHARACTERISTICS OF VARIOUS RESPONDENT GROUPS

Characteristic	New Riders (%) (N=46)	All Riders (%) (N=243)	Free Ticket Users (%) (N=160)	All Respondents (%) (N=1,149)
Commuter Status				
Commuter	94	93	96	93
Noncommuter	6	7	4	7
Postpromotion Commute Mode				
Drive Alone	36	14	21	70
Carpool	7	12	15	9
Tri-Met	55	69	62	17
Other	3	5	3	4
Riding Frequency (Trips per Month)				
0–1	0	0	18	78
2–6	29	20	6	4
7–12	13	14	11	4
13–29	19	17	18	4
30–99	39	49	48	11
Gender				
Male	44	41	37	47
Female	56	59	63	53
Age				
16 and under	0	0	0	0
17–24	11	13	7	5
25–34	30	25	32	21
35–44	27	28	30	30
45–54	12	15	16	16
55–64	7	7	10	11
65 and over	12	11	6	17
Income				
Less than $10,000	10	7	6	4
$10,000 to $14,999	8	6	2	6
$15,000 to $24,999	13	19	19	16
$25,000 to $34,999	26	17	15	20
$35,000 to $49,999	21	24	29	26
$50,000 or More	23	27	29	29

NOTE: Percentages may not add to 100 because of rounding error.

begin riding for another reason, getting a free ticket may be just enough incentive to lure would-be riders onto Tri-Met.

Demographic characteristics of new riders did not vary significantly from those of all riders except that a higher percentage of new riders still drive alone to work and make fewer transit trips per month than other riders.

Probably the single most important factor in the overall success of this project was the nature of the product itself. Line 96 provides direct, nonstop service from the Tualatin park-and-ride lot (with easy freeway access) to downtown Portland. It is unlikely most persons could reach their destination faster if they drove themselves. In addition, parking at the park-and-ride lot is free whereas parking downtown can cost more than $100 per month.

One indicator of the quality of the product is that 28 percent of the respondents to the on-board survey said they heard about the park-and-ride lot and Line 96 express service from a friend or co-worker. This finding also reinforces the notion that word of mouth is a strong advertising tool.

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Direct-Mail Marketing to New Residents

CAROL AMBRUSO

In January 1989, Tri-Met began monthly direct-mail marketing to new residents in 24 target zip codes that were selected for their excellent transit service. Each month, new residents in these zip codes are sent a direct mail packet containing a coupon for 10 free Tri-Met tickets. One-half of the packets also contain an offer for Tri-Met to plan a transit trip of the respondent's choosing. The purpose of the promotion is to capture new riders and retain persons who rode transit before moving at the same or higher riding frequency. Nonriders and those whose riding frequency declined after moving were sent an additional offer of discounts on a monthly pass and Tri-Met tickets and a coupon for a free Transportation Guide. A direct-mail survey to evaluate the promotion was sent to respondents to the January and February 1989 mailings. Key findings from the study were as follows: (a) the original offer received a 30 percent response; (b) over one-third of nonriders before the promotion rode Tri-Met at least twice in a month following the promotion, including 17 percent who rode 7 or more times; (c) more than half of those who were transit riders before moving were retained at the same or greater frequency. The promotion's success demonstrates that moving is a prime time to effect changes in modes of transportation. This promotion succeeded because Tri-Met carefully selected the target market and promoted a good product by providing it to persons at a time when they were making major lifestyle changes.

Every year, thousands of people move into new residences in the Portland metropolitan area—from outside the area and from within. Some of these persons use transit, some have used it in the past, and some have never used it. In January 1989, the Tri-County Metropolitan Transportation District of Oregon (Tri-Met) launched a direct-mail marketing campaign targeting these new residents. The idea behind the campaign was to market transit to persons at a time when they were making major lifestyle changes. This time seemed a golden opportunity to capture new riders and reinforce riding behavior among those who used transit before they moved. The promotion and the results of evaluative research are described.

PROMOTION DESIGN

Tri-Met selected new residents in 24 zip codes as the target audience for the promotion. The zip codes chosen were those with particularly good transit service. Tri-Met chose these zip codes because the agency wished to eliminate as many barriers to riding (including inconvenient service) as possible to elicit the greatest response. A mailing house in Philadelphia that specializes in new-resident promotions was hired to obtain the names and addresses of new residents in the target zip codes and to mail promotional packets. Each month, Tri-Met sends the promotional packet to persons moving into the selected zip codes. At the onset of the promotion, Tri-Met sent packets to all persons who had moved into the area within the past 6 months.

The promotional packet contained the following:

- A letter outlining the personal benefits of riding transit,
- A packet of information about riding Tri-Met, and
- A response coupon that could be redeemed for 10 free Tri-Met tickets.

A short survey to elicit cursory information about the respondent's transit usage appeared on the reverse of each response coupon. One-half of the promotional packets also offered to plan a trip on Tri-Met for the respondent. Tri-Met did not offer trip plans to all new residents for two reasons. First, the agency was uncertain whether there were sufficient staff to plan all requested trips, given an unknown response level. Second, the agency wished to determine if the trip-planning offer made a significant difference in the overall response to the promotional packet.

Tri-Met fulfilled the requests for tickets, information, and trip plans usually within 2 days of receiving the coupons. Information packets sent to persons who did not request a trip plan contained a brochure describing how to ride, a list of ticket and schedule outlets, a piece describing community benefits of mass transit, and a customer comment card. Respondents who requested a trip plan received instructions and schedule information for making the requested trip in addition to the materials listed earlier.

The names, addresses, and responses to the coupon survey were entered into a data base and segmented into three groups:

1. Persons who did not ride transit either before or after moving;
2. Persons who rode transit 20 or more times a month before moving but less than 20 times per month after moving; and
3. Persons who rode Tri-Met 20 or more times per month before and after moving.

Members of the first two groups (62 percent of all respondents) were selected to receive a follow-up offer because they were members of the primary target group (i.e., nonriders or riders whose riding frequency had decreased).

The follow-up offer consisted of three different coupons offering one-half off the price of a book of 10 Tri-Met tickets, 25 percent off the price of a monthly pass, and 50 percent off a Tri-Met guide and map. A graphic presentation of the promotion strategy is shown in Figure 1.

Tri-County Metropolitan District of Oregon, Public Services Division, 4012 S.E. 17th Avenue, Portland, Oreg. 97202.

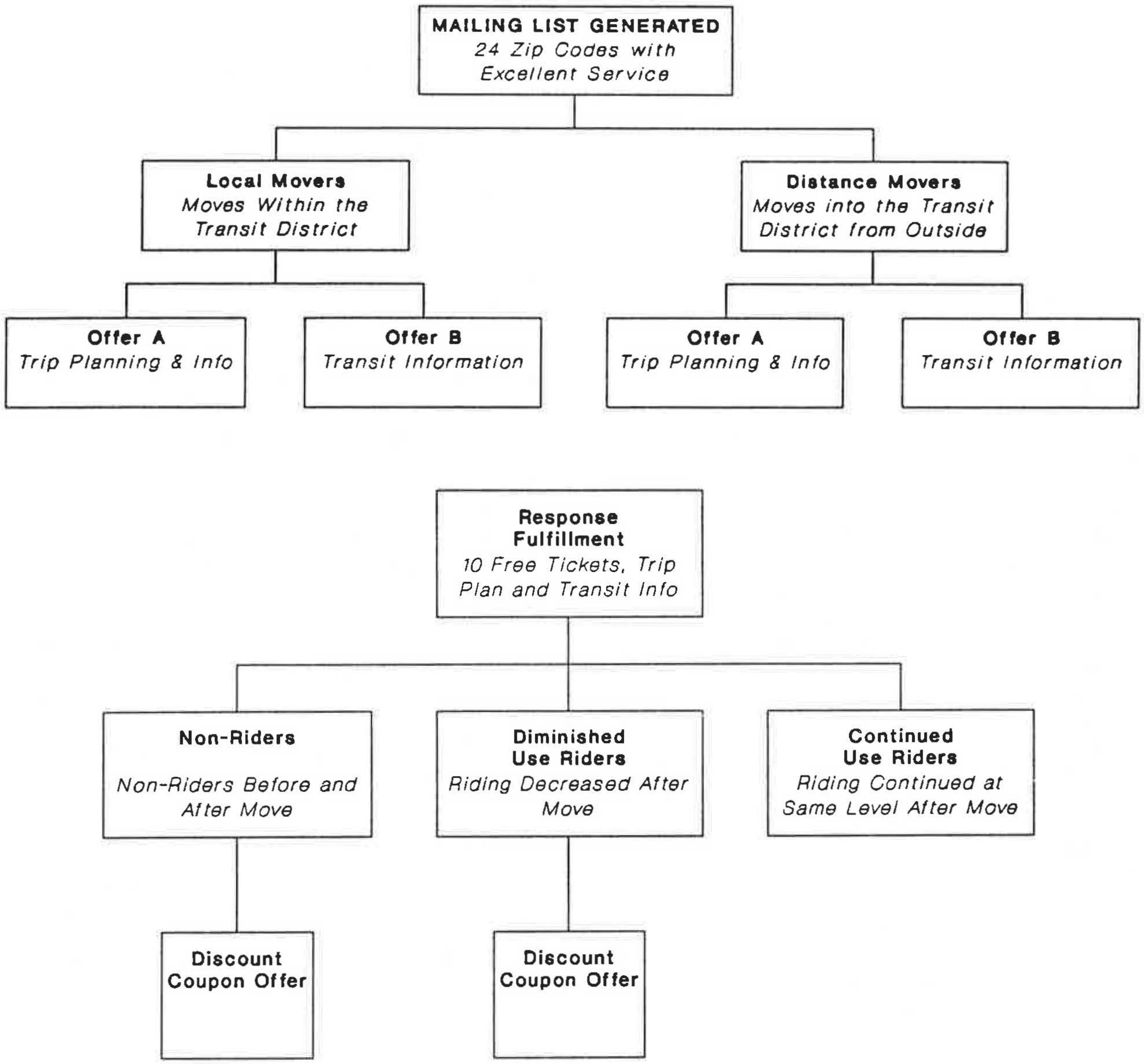

FIGURE 1 New residents promotion flowchart.

PROMOTION OBJECTIVES

The primary objective of the program was to increase ridership by retaining existing riders and capturing new riders. The specific objectives that follow were developed on the basis of the experience of other transit properties with similar programs.

1. Generate a 15 percent response rate to the initial mailing.
2. Have 50 percent of the initial respondents make use of the promotional offer.
3. Have 10 percent of the initial respondents make use of the follow-up offer.
4. Have 10 percent of the initial respondents who did not previously use transit become regular transit riders. (A regular rider is defined as a person who makes seven or more transit trips per month).
5. Have 50 percent of the initial respondents who were riders continue riding Tri-Met at the same or greater frequency.

STUDY METHODOLOGY

The research design to evaluate the effectiveness of the promotion included the following:

- A short survey on the back of the initial response coupon. The survey obtained cursory information about each respondent's transit usage before and after moving. Tri-Met used this information to select those to receive the follow-up offer. Each coupon also contained a unique identification code that appeared on other research materials, allowing Tri-Met to track each respondent throughout the project.

- A tally of response coupons returned from the initial offer each month. This tally allowed Tri-Met to determine the response rate to the initial mailing on a monthly basis.
- A research mailing sent to respondents to the January and February initial mailings who met the criteria to receive a follow-up offer.
- A record of coupons from the follow-up offer that were redeemed.

A secondary research goal was to quantify the amount of revenue (in actual tickets used) Tri-Met gave away. This amount is important for estimating ridership as estimates are revenue based.

STUDY RESULTS

Response to the Initial Mailing of the Promotional Packet

In January and February 1989, 6,816 promotional packets were mailed to new residents in the Portland area. A total of 2,241 persons (32 percent) responded. Experience with direct-mail promotions and research has indicated a definite bias in responses to promotions of this type. In general, only persons with at least marginal interest in the product or service being offered respond. In this instance, many nonriders were eliminated from further promotions or scrutiny because they did not respond to the initial mailing.

Responses to the initial offer far exceeded Tri-Met's goal of 15 percent. In January and February 1989, the response rate was greater than 30 percent. The overall response rate for the first 4 months was 30 percent.

The response rate for Offer A (trip planning) was consistently 3 percentage points lower than for Offer B (information only). Although this difference in response rates is not large, the consistency of response differences is interesting. Perhaps some recipients of Offer A thought they were required to request a trip plan to obtain the free tickets and were unable or unwilling to do so.

The trip planning aspect of Offer A was somewhat less appealing to respondents than Offer B (information only). In the first 4 months of the promotion, only 39 percent of those who were offered trip planning actually submitted a trip plan request. The remainder requested information only. Among those who did request a trip plan, only 18 percent were persons who moved from outside the Tri-Met service district. The remainder were persons who made local moves. This finding reinforces the idea that trip planning is a desirable service for persons changing residences no matter how long they have lived in the general area.

Figure 2 shows the response to the initial mailing for each of the first 4 months of the promotion, broken down by offer. The grouping on the far right represents the combined response for all 4 months. The reverse of the response coupon in the initial offer contained a short questionnaire designed to yield cursory transit usage information about the respondent.

In all, 42 percent of respondents to the initial mailing were nonriders after moving, including 7 percent who rode transit before they moved. The remaining 58 percent of respondents reported riding Tri-Met at least two times per month after moving.

Although it is difficult to pinpoint the reasons for a change in travel behavior, there is evidence to suggest that moving from one home to another may precipitate just such a change. In a November 1988 poll (Tri-Met Attitude and Awareness Study), 9 percent of respondents who had stopped riding Tri-Met cited moving as their primary reason. Responses to the coupon survey indicated that 42 percent of all respondents changed their travel behavior when they moved; 28 percent increased their transit travel frequency and 14 percent either stopped riding transit or decreased their transit usage. Fully 8 percent of respondents who did not ride transit before moving began riding more than 20 times per month even before receiving the promotion.

The target audience for the follow-up offer was selected on the basis of information from the coupon survey regarding transit use before and after moving. Table 1 presents the

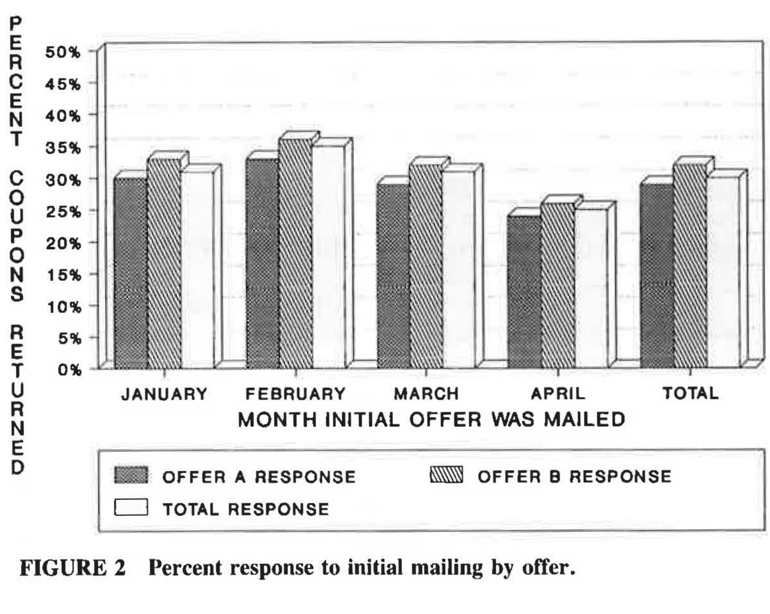

FIGURE 2 Percent response to initial mailing by offer.

TABLE 1 NEW RESIDENTS TRANSIT USAGE—SEGMENTATION FOR FOLLOW-UP MAILING

Transit Trips Per Month Before Move	Transit Trips Per Month After Move				
Count Tot Pct	0-10	11-20	21-30	31+	Row Total
0-10	2466 55.4	226 5.1	97 2.2	268 6.0	3057
11-20	126 2.8	191 4.3	27 .6	35 .8	379
21-30	74 1.7	42 .9	105 2.4	26 .6	247
31+	196 4.4	64 1.4	33 .7	476 10.7	769
Column Total	2862 64.3	523 11.7	262 5.9	805 18.1	4452 100.0

▬ Target Group for Follow-up Offer

target audience for the follow-up offer for the first 4 months of the promotion.

Follow-up offer recipients were nonriders before and after moving, riders who used transit fewer than 11 times per month, and riders whose transit usage decreased to less than 20 trips per month after moving.

Tri-Met mailed follow-up offers containing three discount coupons in late April to 1,387 of the 2,241 January and February respondents to the initial mailing. The coupons expired on August 15, 1989. By the end of May, 150 coupons had been redeemed, as follows:

Coupon Type	*Coupons Redeemed*
50 percent off, one book of Tri-Met tickets	75
25 percent off, one regular Tri-Met monthly pass	45
50 percent off, one Tri-Met transportation guide	30
Total	150

Because each respondent could redeem one, two, or three coupons, and because coupons were redeemed at various pass and ticket outlets, calculating an exact response rate was not possible. Coupon redemptions in May indicate a response rate between 5 and 11 percent.

Direct Mail Survey Results

At the end of April, direct mail surveys were sent to the 1,387 respondents who were selected to receive the follow-up offer. Separate surveys were sent to persons who initially received Offer A (trip planning) and persons who received Offer B (information only). A total of 472 surveys were returned for a response rate from the target group of 33 percent. The maximum margin of error for a sample of this size is ±4.5 percent at the 95 percent confidence level.

Overall Response to Information Packets

In all, the packets sent to respondents to the original mailing were perceived as being very useful. All respondents were sent 10 free tickets; a list of pass, ticket, and schedule outlets; and a brochure outlining how to ride Tri-Met. In addition, Offer A respondents who requested a trip plan were sent instructions for making the trip they requested and appropriate schedule information. Table 2 presents each packet information piece by perceived usefulness.

Respondents thought the packet provided complete information. When asked, "Is there anything else Tri-Met could provide you with to help make using buses or MAX easier or more pleasant?", the most common response was "nothing else" (33 percent of all comments). Other comments mentioned often were "you're doing a good job" (10 percent), a need for more service (9 percent), a need for route or schedule information (8 percent), "thanks for the tickets" (6 percent), "send more free tickets" (6 percent), and safety or security concerns (5 percent).

Response to Trip Planning Offer

In all, 16 percent of the survey respondents actually requested a trip plan when responding to the original mailing. This number represents just over one-third of the respondents who were sent Offer A (trip planning).

Respondents who remembered requesting a trip plan were asked a series of questions related to that trip. Their responses must be viewed with caution. Because the number of respondents who remembered asking for a trip plan is so small (n = 51), the margin of error for these responses increases to ±14 percent. Therefore, the following discussion should be viewed

TABLE 2 USEFULNESS OF PACKET INFORMATION

Information Piece	Very Useful	2	3	4	Not at All Useful
10 Free Tickets					
Group 1 (Trip Plans)	90%	4%	4%	1%	1%
Group 2 (No Trip Plans)	92	5	2	1	0
List of Schedule Outlets					
Group 1	34	16	24	10	15
Group 2	32	13	27	7	21
How to Ride Brochure					
Group 1	31	22	29	9	9
Group 2	21	23	33	10	13
Trip Plan Information*					
Group 1	49	20	17	10	4
Bus/MAX Schedule*					
Group 1	65	18	10	3	4

* Sent only to persons who requested a trip plan

as an indicator only and should not be assigned statistical validity.

More than half of the respondents who remembered receiving a trip plan actually made the trip. The majority of these were work trips (54 percent), followed by shopping (12 percent), and school (8 percent). Nearly all respondents found that their trip planning information was easy to understand (84 percent very easy, 14 percent somewhat easy, 2 percent somewhat difficult). Three-quarters of those who made their requested trip were local movers, whereas one-quarter were persons moving into the Tri-Met district.

Persons who did not make the trip they requested were asked why not. Reasons mentioned in order were as follows: no need (35 percent), used my car (18 percent), takes too long (13 percent), no time (6 percent), no service (6 percent), and plan to later (6 percent). Comments written in the survey margins indicated that several respondents took advantage of the trip planning offer to obtain information on riding transit in the event of bad weather or a car breakdown, etc.

Free Ticket Usage

All respondents were asked who used the free tickets. Three-quarters of all respondents reported using at least one ticket personally, 35 percent gave one or more tickets to a household member, 12 percent gave at least one ticket to someone outside the household, and 28 percent plan to use their tickets at a later date.

Table 3 presents the actual number of tickets used and by whom. Each respondent received 10 tickets, which were distributed among the various user groups mentioned. A total of 4,080 tickets were distributed, 6 percent of which were unaccounted for.

Changes in Transit Usage

As discussed earlier, moving is a prime time to intervene to affect transit ridership. In all, 47 percent of respondents to

TABLE 3 FREE TICKET USAGE (N = 408)

	USER GROUP					
NUMBER OF TICKETS	Respondent	Household Member	Gave Away	Plan to Use	Don't Plan to Use	Total
1	14	10	6	4	0	34
2	100	78	34	24	2	238
3	36	12	3	9	0	60
4	140	80	16	56	0	292
5	175	125	30	65	0	395
6	138	72	6	132	0	348
7	63	14	7	42	0	126
8	152	80	32	96	0	360
9	18	18	9	45	0	90
10	1,250	290	120	250	0	1,910
TOTAL	2,086	779	263	723	2	3,853
Pct of Tot.	51%	19%	6%	18%	0%	94%

the direct-mail promotion changed their transit riding behavior at the time they moved; 17 percent increased their riding frequency; and 30 percent decreased their riding frequency.

The promotion appears to have had a significant effect on respondents' transit usage. After moving, 60 percent of existing riders decreased their riding frequency or stopped riding altogether. After receiving the promotion, 16 percent of these respondents began riding transit with the same or greater frequency than they had before they moved. Among nonriders, 37 percent began riding after receiving the promotion.

Overall, then, between the time respondents mailed in the coupon for 10 free tickets and the time they answered the survey (about 3 months later), 42 percent increased their transit usage, 31 percent continued to ride about the same amount, 12 percent decreased their transit usage, and 14 percent remained nonriders.

When asked if they ride more or less often after receiving the promotion, 41 percent said they ride more often, 2 percent said they ride less often, and 58 percent ride about the same amount as before. This 58 percent includes persons who were nonriders both before and after the promotion.

Table 4 presents respondents' transit usage before moving, after moving, and after receiving the free tickets. As indicated, 43 percent of persons who were nonriders before moving began using transit after they moved. An additional 37 percent began riding after they received the free tickets. There was a substantial drop-off in riding frequency among riders (particularly among frequency and heavy riders) after moving. The promotion seems to have mitigated some of this drop-off although riding frequency in the higher categories did not return to previous levels.

After looking at the effectiveness of the promotion overall, Tri-Met evaluated the effectiveness of each of the two offers in persuading persons to use Tri-Met. Offer A (trip planning) appears to have been slightly more persuasive than Offer B (information only) both among riders and nonriders. In all, 69 percent of Offer A recipients who were nonriders after moving began riding Tri-Met. By comparison, 65 percent of Offer B recipients who were nonriders after moving began riding Tri-Met.

Among those who rode Tri-Met after moving, 27 percent of Offer A recipients increased their transit usage compared with 21 percent of Offer B recipients. Both offers were effective at retaining existing riders at the same level of transit usage they had before the promotion.

There appears to be little relationship between transit usage decreases and the offer riders received. Twenty-one percent of respondents who were riders after moving decreased their transit usage. These riders were divided evenly between those who received Offer A and those who received Offer B. More than half of these riders began riding on their own initiative after moving and either decreased their riding frequency or stopped riding altogether after a short period of time.

Demographic Characteristics of Respondents

Demographic characteristics of respondents are presented in Table 5. Respondents are divided into three groups: nonriders, new riders, and old riders. Nonriders are persons who did not ride transit before or after moving. New riders are persons who did not ride transit before moving, but began riding after moving and before receiving the promotion. Old riders are persons who used transit before and after moving.

Demographic characteristics of new riders are similar to those of existing Tri-Met riders. The majority of new riders are 25 to 44 years old, earn less than $30,000 per year, rent their residences, and are employed. New riders are less likely to work in a professional occupation and more likely to be a manager, secretary, student, or retired.

Persons who used transit before the promotion appear to be somewhat more mobile than nonriders or those who just began riding as evidenced by the differences in length of residence presented in Table 5.

In looking at where new riders come from, it is important to note that they are spread throughout the target zip codes. These zip codes were chosen because they offered some of the best transit service in the district. Once again, a good product was key to successful marketing.

TABLE 4 CHANGES IN TRANSIT USAGE OVER TIME, BY RIDER AND NONRIDER BEFORE MOVING

RIDERSHIP STATUS BEFORE PROMOTION	Non-Rider	Light Rider	Occasional Rider	Frequent Rider	Heavy Rider
NON-RIDERS (n=254) (0-1 Trips/Month)					
Before Moving	100%	0%	0%	0%	0%
After Moving	57	23	7	5	8
After Promotion	20	37	15	15	13
RIDERS (n=137)					
Before Moving	0%	13%	12%	22%	53%
After Moving	19	21	16	17	27
After Promotion	10	22	18	15	35
ALL RESPONDENTS					
Before Moving	64%	5%	4%	8%	19%
After Moving	42	23	10	9	16
After Promotion	17	32	16	14	21

TABLE 5 DEMOGRAPHIC CHARACTERISTICS OF SURVEY RESPONDENTS

CHARACTERISTIC	RIDERSHIP STATUS AFTER PROMOTION: All Respondents	Non-Riders	New Riders	Old Riders
AGE				
18 and Under	2%	0%	4%	0%
19 to 24	12	5	12	15
25 to 34	31	41	32	26
35 to 44	27	36	24	29
45 to 54	10	7	9	12
55 to 64	7	7	8	6
65 and Over	11	5	11	12
	100%	100%	100%	100%
INCOME				
Less than $10,000	16%	7%	16%	19%
$10,000 to $15,000	15	12	11	20
$15,000 to $20,000	14	12	11	17
$20,000 to $25,000	11	12	13	9
$25,000 to $30,000	10	12	12	8
$30,000 to $40,000	17	26	16	16
$40,000 to $50,000	6	7	7	5
More than $50,000	11	12	14	6
	100%	100%	100%	100%
OWN/RENT HOME				
Own	33%	41%	39%	21%
Rent	67	59	61	79
	100%	100%	100%	100%
DISTANCE OF MOVE				
Inside District	80%	79%	77%	84%
From Outside District	20	21	23	16
	100%	100%	100%	100%
LENGTH OF RESIDENCE				
Less than 6 Months	46%	44%	44%	54%
7 to 12 Months	44	43	44	36
1 to 2 Years	3	3	4	3
3 to 5 Years	4	8	4	3
More than 5 Years	4	3	5	3
	100%	100%	100%	100%
JOB CLASSIFICATION				
Professional	32%	46%	35%	24%
Management	10	7	13	8
Sales	5	5	4	5
Secretarial	11	0	12	15
Laborer	4	7	2	8
Technician	7	3	6	9
Student	9	12	11	4
Retired	12	7	11	14
Unemployed	4	3	4	4
Other	6	10	2	10
	100%	100%	100%	100%
RIDERSHIP STATUS BEFORE MOVE				
Non-Rider	64%	100%	100%	0%
Light Rider	5	0	0	13
Occasional Rider	4	0	0	12
Frequent Rider	4	0	0	22
Heavy Rider	19	0	0	53
	100%	100%	100%	100%

TABLE 5 *(continued on next page)*

TABLE 5 *(continued)*

	RIDERSHIP STATUS AFTER PROMOTION			
CHARACTERISTIC	All Respondents	Non-Riders	New Riders	Old Riders
RIDERSHIP STATUS AFTER MOVE				
Non-Rider	42%	100%	46%	19%
Light Rider	23	0	28	21
Occasional Rider	10	0	9	16
Frequent Rider	9	0	6	17
Heavy Rider	16	0	11	27
	100%	100%	100%	100%
RIDERSHIP STATUS AFTER PROMOTION				
Non-Rider	17%	100%	3%	10%
Light Rider	32	0	45	22
Occasional Rider	16	0	19	18
Frequent Rider	14	0	17	15
Heavy Rider	21	0	16	35
	100%	100%	100%	100%
OFFER RECEIVED				
A: Trip Planning	46%	48%	50%	42%
B: Information Packet	54	52	50	58
	100%	100%	100%	100%

COST-BENEFIT ANALYSIS

The purpose of this cost-benefit analysis was to determine the cost to Tri-Met for each new rider captured and each rider who was convinced to continue riding transit with the same or greater frequency as a result of the promotion. Costs were divided into three categories:

1. Development and production,
2. Mailing costs, and
3. Revenue lost or given away.

Labor costs for work done by Tri-Met staff are not included. Other labor costs are included in the appropriate categories.

Development and Production Costs

Development and production costs refer to the monies associated with designing the creative approach and printing the finished materials. The development and production costs for the promotion totaled $10,048.69, including costs for the original offer, the follow-up coupon offer, and the information packets.

The costs of the original offer ($2,347.50) and the follow-up coupon offer ($6,598.44) were prorated over 2 years ($8,945.94 per 24 months = $372.75/month), because they were printed in sufficient quantity to cover monthly mailings for that time period.

Information packet materials were prorated over 6 months ($1,102.75 per 6 months = $183.79/month). After prorating, the total monthly development and production cost for the promotion was $556.54. Total development costs for January and February are calculated as follows:

Item	*Cost ($)*	*Cost per Month ($)*
Original offer	195.63	97.81
Follow-up coupon offer	549.87	274.93
Information packet materials	367.58	183.79
Total production/development costs	1,113.08	556.54

Mailing Costs

Mailing costs include postage and fees charged by the mailing house. Mailing costs for January and February were as follows:

Item	*Cost ($)*
Original offer	2,862.08
Follow-up coupon offer	548.08
Total mailing costs	3,410.16

Revenue Lost or Given Away

Lost revenue is revenue Tri-Met would have collected in the course of normal operations had there been no promotion. For example, if Tri-Met gives a book of 10 all-zone tickets to a regular Tri-Met rider, Tri-Met loses $10.50 (ticket book price) that the rider would otherwise have paid through purchasing tickets or paying the cash fare.

Revenue given away refers to the value of tickets or coupons given to persons who would not have purchased them otherwise. From the 6,816 original offers mailed, Tri-Met received 2,193 responses. Everyone who responded was sent an information packet containing a book of 10 all-zone tickets valued at $10.50 each, for a total value of $23,026.50. Of the 2,193 persons who responded, 806 persons rode Tri-Met at least 11 times per month after moving. It is reasonable to assume that these persons used the free tickets instead of a fare they would normally purchase—resulting in lost revenue to Tri-Met.

806 Nontarget respondents · $10.50

= $8,463.00 (lost revenue)

For purposes of allocating the remaining ticket revenues into lost revenue or revenue given away, the remaining 1,387 persons in Tri-Met's target market were divided into three groups based on survey returns:

1. New riders and riders retained at the same or higher level as a result of the promotion (n = 587).
2. Nonriders and persons who rode fewer than 7 times per month following the promotion (n = 408).
3. Persons who rode Tri-Met before moving whose riding frequency decreased or remained constant despite the promotion. All respondents in this category still ride 7 or more times per month (n = 392).

Ticket revenue from Groups A and B is considered to be revenue given away because the tickets would probably not have been purchased if there were no promotion.

Ticket revenue from Group C is considered to be lost revenue because members of this group would probably have paid for their rides if they had not had the free tickets.

Ticket revenue given away (995 · $10.50) = $10,447.50

Lost ticket revenue (392 · $10.50) = $4,116.00

Another source of revenue that must be considered is the follow-up coupon offer. This offer contained three coupons for three different discounts: 50 percent off a book of 10 tickets, 25 percent off a monthly pass, and 50 percent off a transportation guide.

In the month after the follow-up offer was sent to January and February respondents, coupons were redeemed for 26 two-zone passes, 19 all-zone passes, 49 books of two-zone tickets, 26 books of all-zone tickets, and 30 transportation guides. The total amount discounted off the regular price was $701.50. (This cost could be higher as respondents had 3.5 months to redeem their coupons). Because it is not possible to know which respondents used these coupons, this money is considered to be revenue given away.

Total revenue given away ($10,447.50 + $701.50) = $11,149.00

Total revenue lost ($8,463.00 + $4,116.00) = $12,579.00

Cost Per Rider Attracted or Retained

When determining the cost per person on the mailing list and the cost per new rider attracted or retained, only actual costs to Tri-Met are included. Because "revenue given away" would not have been collected in the absence of this promotion, it is not a farebox loss to Tri-Met and hence is excluded from the cost calculations. The total cost to Tri-Met for the new residents promotion in January and February is computed as follows:

Item	*Cost ($)*
Development and production	1,113.08
Mailing	3,410.16
Lost revenue	12,579.00
Total	17,102.24

Total cost per new rider or rider retained = $29.13

Total cost per person on the mailing list = $ 2.50

CONCLUSIONS

Assessments of how well the promotion worked to achieve the stated objective were as follows:

1. Generate a 15 percent response to the initial mailing.

Responses to the initial offer more than doubled Tri-Met's objective of 15 percent in January and February. The overall response rate for the first 4 months of the promotion was 30 percent.

2. Have 50 percent of the initial respondents make use of the promotional offer.

Three-quarters (75 percent) of all respondents to the survey reported using at least one of the free tickets. In addition, respondents to the initial mailing who were not selected to receive the follow-up offer were persons who ride Tri-Met 11 or more times per month. It is reasonable to assume that all these respondents used at least one free ticket, bringing the total number of initial respondents who used the promotional offer to well over 50 percent.

3. Have 10 percent of the initial respondents make use of the follow-up offer.

In all, 1,387 follow-up offers were sent in late April to targeted respondents to the January and February initial mailings. In May, 150 coupons were redeemed. Because respondents could redeem one, two, or three coupons, it was impossible to calculate an exact response rate. The response rate was between 5 and 11 percent of the target group on the basis of coupon redemptions in May. The response rate for the entire group of initial respondents (n = 2,241) was between 2 and 7 percent.

4. Have 10 percent of the initial respondents who did not previously use transit become regular transit riders. (A regular rider is defined as a person who makes seven or more transit trips per month.)

Again, the promotion was successful beyond Tri-Met's expectations. Among all nonriders, 37 percent said they rode Tri-Met at least twice per month following the promotion including 17 percent who rode at least seven times per month. In fact, 5 percent of all nonriders began riding Tri-Met 30 or more times per month after receiving the promotion.

5. Have 50 percent of the initial respondents who were riders continue riding Tri-Met at the same or greater frequency.

In all, 64 percent of persons who were transit riders before moving were retained at the same or greater frequency. Many of these respondents were not included as part of the target market for the follow-up offer because they were already riding of their own volition at least 11 times per month after moving.

For riders who were selected to receive the follow-up coupon, 56 percent of those surveyed who used transit before moving continued to ride at least as much as they had before. However, only 16 percent of these retained riders can be attributed to the promotion. The remainder resumed riding at the same frequency before receiving the promotion.

There is no statistically significant difference in the ability of Offers A and B to attract new riders or retain existing ones. Offer A (trip planning) consistently received an initial response three percentage points below the response to Offer B. Among persons who responded to the initial offer, there was little difference in the number persuaded to ride transit as a result of receiving one offer or the other.

The information packets were complete. When asked what else Tri-Met could do to make using transit easier, the most common response was "nothing else." Respondents found the free tickets to be the most useful item in the packet. The majority of those who received trip plans said the schedule information was also very useful.

More than half of the free tickets were used personally by the respondents, 19 percent were used by someone in the respondent's household, and respondents planned to use 18 percent of the tickets at a later date. Only 6 percent of all tickets were given to someone outside the respondent's household.

Tri-Met plans to conduct a study of new riders captured through the new residents promotion to determine how long they continue to use transit. The study involves contacting new riders once each quarter for an entire year. It is scheduled to begin in January 1991. Information from this study will help Tri-Met to further evaluate the costs and benefits of this type of promotion. The cost of attracting new riders and retaining existing ones was relatively inexpensive. After including revenue from giving tickets to regular riders, the cost per rider captured or retained was $29.13. Tri-Met may wish to lower the amount of lost revenue, and thus, cost per rider attracted or retained, by decreasing the number of free tickets offered from 10 to 5. It is not possible to predict what effect, if any, decreasing the number of tickets offered will have on response rates.

Tri-Met may wish to consider expanding the program to include more zip codes. Expanding the program will probably result in a lower overall response rate because transit service in other areas is not quite as good as that in the currently targeted zip codes. On the other hand, the program will reach more people, resulting in more exposure, and possibly a higher number of new riders.

Tri-Met did an excellent job of ferreting out its target market. The blanket mailing to new residents appealed to persons at a time when they were making major lifestyle changes. Experience tells us that those who responded were persons with an elevated interest in using transit. Of the respondents to the initial mailing, 65 percent were nonriders before they moved.

The new residents program overall was highly successful. Tri-Met's expectations were exceeded in four out of five objective areas. In addition to selecting a prime target market, the key to the promotion's success was providing complete information about a good product to persons at a time when they were making major lifestyle changes.

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Lessons from the Broome County Distance-Based Fare Demonstration: Effects of Zone Fares and Off-Peak Discounts on Ridership, Revenue, Pass Sales, and Public Opinion

STEPHEN ANDRLE, JANET KRAUS, AND FRANK SPIELBERG

The Broome County, New York, Department of Public Transportation was the test site for an UMTA-sponsored demonstration of distance-based fares over the period 1986 through 1988. Binghamton is the major city in Broome County. The service area also includes the cities of Endicott and Johnson City and the Town of Vestal. Over the demonstration period, two fare changes were put in place. An interim fare structure was in effect in Calendar Year 1987 that featured half-fares for all riders in the off-peak period. A fare increase including the introduction of zone fares was implemented in January 1988. The full range of demonstration activity is discussed—off-peak fare reduction, introduction of zone changes, effect on pass sales, driver reaction, public reaction, and effect on university student ridership. The events of the demonstration are so intertwined that it is difficult to separate one topic from the other and still have a meaningful discussion. The impact of each element, therefore, is discussed as it relates to the whole. The demonstration showed that zone fares can be introduced effectively in a small transit system such as Broome County Transit. However, revenue effects are small. Whether or not to adopt zone fares should depend primarily on a system's policy regarding fare differentiation.

When transit systems were privately owned, distance-based or zone fare systems were common. Many large cities retained zone fares after public takeover because of the length of their routes. Small- and medium-sized systems generally opted for simple, flat fares, particularly when outside funding support became available. Broome County Transit, in New York, had a zone system in the past but had not used distance-based fares since becoming publicly owned.

Broome County Transit (BC Transit) is the fixed-route service component of the Broome County Department of Public Transportation. It provides service on 13 regular routes and 4 additional peak commuter routes with a fleet of 40 buses. Service is available throughout the tri-city area of Binghamton, Johnson City, and Endicott, plus the Town of Vestal. Its service area population is approximately 215,000.

As part of an UMTA-funded demonstration, BC Transit reintroduced zone fares in January 1988. A year's worth of data are now available to permit a full evaluation of the new distance-based fare structure. Information on the implementation process also is available.

Although the demonstration began in 1986, implementation of the distance-based fares was delayed 18 months by the one-time availability of special funds from New York State. The funds had to be spent in 1987, so a fare restructuring and decrease were implemented in 1987. When the zone fares and a fare increase were implemented in January 1988, these changes followed a period of artificially low fares in 1987, rather than the 1986 base period. The chronology clearly complicates the interpretation of results and mixes the impact of zone fares with the impact of other fare restructuring changes.

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OVERVIEW OF THE FARE STRUCTURE

This demonstration has a complicated fare history. Table 1 presents the fares in effect at the beginning of the demonstration in 1986, the interim 1987 fare structure, and the 1988 zone-based fare structure that was the subject of the demonstration. In 1987, half-fares were introduced in the midday base period for all riders, rather than just senior citizens and handicapped individuals. This measure actually was a 5-cent fare increase for seniors in the midday. The other big change in 1987 was extending the half-fare senior citizen fare to the full day.

In 1988, fares were increased as presented in Table 1, but half-fare was retained for all midday riders. The principle features of the 1988 demonstration fare policy are as follows:

- Peak-period fares were increased by 20 percent from 50 to 60 cents;
- Zone fares were introduced at 10 cents per crossing in the peak period and 5 cents in the off-peak period;
- Half-fares of 30 cents (and zone fares of 5 cents) were available to all riders in the off-peak period, eliminating a special fare for senior citizens and disabled persons;
- Prepaid fares such as monthly passes and tokens exempted the rider from zone charges; and
- Transfers remained free.

This fare structure offset the 20 percent peak fare increase with the low off-peak fare. A large peak-base differential was

TABLE 1 BC TRANSIT FARE STRUCTURES

CATEGORY	Year in Effect 1986	1987	1988
ADULT CASH			
Regular Route			
Peak	$ .50	$ .50	$ .60
Base	.40	.25	.30
Zone Crossing			
Peak	- -	- -	.10
Base	- -	- -	.05
Commuter Route	.75	.90	1.00
E & H CASH			
Peak	.50	.25	.60 *(a)*
Base	.20	.25	.30 *(a)*
STUDENT CASH	.35	- -	- -
TRANSFERS	Free	Free	Free
PREPAID MEDIA			
Tokens (20)	9.00	9.00	12.00
Tickets: Commuter Ten Ride	6.75	6.75	9.00
Monthly Passes			
Regular Route	18.00	18.00	24.00
Commuter Route	27.00	- -	- -
E & H	- -	- -	16.00
Student	- -	- -	16.00

(a) special identification no longer required

established. In 1986, the fare was 50 cents in the peak and 40 cents in the off-peak. In 1988, it was 60 cents peak and 30 cents base plus zone charges.

EXPECTATIONS

What were the expectations for zone fares? The primary expectation was pricing flexibility. BC Transit management saw distance-pricing as a way to expand alternatives to periodic across-the-board fare increases. When this project began in 1986, BC Transit already had a time-of-day differential, a peak-base fare for all riders and a half-fare midday discount for senior citizens and disabled persons. It also had a discount student fare and free transfers. Zone fares added another pricing option to an already differentiated fare structure.

It also was hoped that pass and token sales would increase as a result of the policy to excuse zone charges for prepaid media users. There are many operational and financial advantages with the increased use of prepaid fares such as improved boarding times and better cash flow.

The traditional reason for introducing distance-based fares is to relate the cost of a ride to the resources consumed in providing it, resulting in improved fare equity. There had never been any public complaints about the inequity of the flat fare system in Broome County, however, so improving fare equity was not the primary motivating force. As originally conceived, the zone fare demonstration would have included a fare reduction for short trips as well as an increase for long trips. This element was dropped in favor of the reduced midday fare. Because of the sharp increase in peak fares in 1988 and the deep midday discount introduced both in 1987 and 1988, it was not possible to isolate trip-length effects of zone fares.

DATA LIMITATIONS

Student riders are an important element of total ridership. Students at the State University of New York (SUNY) at Binghamton comprised 34.7 percent of BC Transit's ridership in 1986. They paid their fare with a special token. If they did not have a token, they showed a student ID and paid a 35-cent cash fare. The 1987 fare structure eliminated this cash fare option because the base period fare was only a quarter. Further, the contract between SUNY and BC Transit was modified in 1987, eliminating student tokens and enabling any student to ride free by showing an ID. The result of all these changes is an apparent drop in the percentage of total ridership that students represented, primarily because those who used to pay the special 35-cent cash fare could no longer be identified separately in the drivers' counts. According to the dashboard counts, the proportion of student riders dropped sharply.

Year	*Student Riders (%)*
1986	34.7
1987	20.6
1988	22.4

There was no reason to expect such a drop. Rather, the effect was a result of changing the method of fare payment.

This is important because the zone fare impact analysis was conducted primarily on nonstudent ridership. Students riding free were not impacted by the 1988 fare structure change, and, therefore, their behavior should not have been included. Further, student revenue for the free riders was not reported with farebox revenue. It was reported as contract revenue and was a negotiated annual amount that does not reflect actual ridership. For these reasons, student riders were excluded from the analysis as much as possible. As the proportions indicated, however, the ability to accurately identify all student riders was lost in 1987. Some students appeared in the farebox ridership and revenue statistics for 1987 and 1988. For example, there was a 24 percent jump in nonstudent ridership in 1987. At first glance, this appeared to be caused by the lower off-peak fares. On closer examination, it was learned that total ridership increased only 2.1 percent, leading to the surmise that at least part of the increase in nonschool riders was caused by the classification problem.

AGGREGATE RIDERSHIP AND REVENUE IMPACTS

In the 3-year trend in total monthly ridership and net (nonschool) ridership shown in Figure 1, net ridership increased beginning in January 1987. No dramatic change occurred in total ridership. This is further proof of the measurement effect of dropping the student cash fare.

Table 2 presents system-wide ridership, nonschool ridership, and revenue for the 3 years of the demonstration. Calculating the straight line elasticities on these composite data yields -0.213 for 1986–87 and -0.244 for 1987–1988. The straight-line elasticity is defined as the percentage change in ridership divided by the percentage change in revenue.

Even though the 1986–1987 case involves a fare decrease and the 1987–1988 case involves a fare increase, the elasticities are very similar and fall into the expected range. In their extensive reference on elasticities, Mayworm and Lago (*1*) report the mean elasticity over a sample of 67 cases as -0.28 ± 0.16. They also observe that "elasticities for fare increases do not differ from those for fare decreases." With results consistent with their findings, the Broome County demonstration adds another data point to their work.

For only nonstudent riders, the elasticity for 1987–1988, when the zone fares were introduced, was -0.359. This also is within the range reported by Mayworm and Lago (*1*). It also conforms to the industry-wide one-third rule of thumb known as the "Simpson & Curtin formula."

The elasticity for the 1986–1987 fare decrease cannot be calculated directly because of the problem with the classification of student fares discussed previously. Nonetheless, as

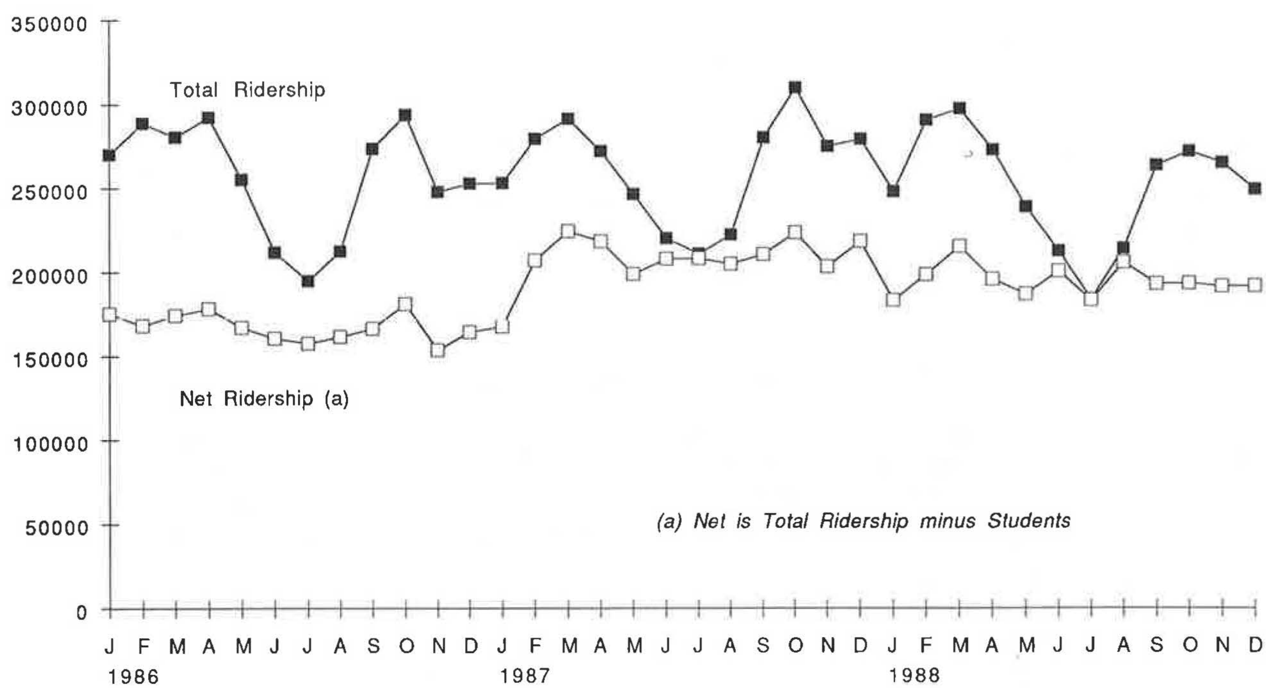

FIGURE 1 Ridership trends.

TABLE 2 TOTAL AND NONSTUDENT RIDERSHIP AND REVENUE

	Total Ridership		Nonschool Ridership		Farebox Revenue	
Year	Number	Change (%)	Number	Change (%)	Amount ($)	Change (%)
1986	3,075,563	–	2,007,810	–	812,305	–
1987	3,139,753	2.09	2,492,743	24.15	732,583	(9.81)
1988	3,007,674	(4.21)	2,338,610	(6.18)	858,462	17.20

a test, the 1987 nonschool ridership was estimated by assuming that students remain the same proportion of total ridership and by applying the 1986 student percentage (34.7 percent) to the 1987 aggregate ridership (3,139,753). Calculating the elasticity for 1986–1987 using the resultant estimate of nonschool riders (2,050,259) yields an elasticity of −0.232. This, too, is within the expected range.

Mayworm and Lago (*1*) also report that there is some evidence that fare elasticities are smaller for fare decreases than for fare increases, but their data would not conclusively support such a finding. The Binghamton data calculated on nonschool riders also suggest a lower elasticity for a fare decrease, but the values lie within the confidence interval of the data assembled by Mayworm and Lago (*1*). No definitive statement can be made on the basis of the Binghamton results.

As expected, revenues were down during the 1987 interim fare changes and increased in January 1988 when fares were increased and zone fares implemented. The 3-year trend line is shown in Figure 2. Revenue from pass sales increased slightly as a proportion of total farebox revenues, mostly because of the introduction of new pass media. Pass sales will be discussed in more detail later.

RIDERSHIP AND REVENUE BY TIME PERIOD

Before the demonstration project, BC Transit had established a peak/off-peak fare differential. The fare changes that occurred during the demonstration further discounted the off-peak trip. Thus, some riders could be expected to shift discretionary trips from the weekday peak to the weekday off-peak and Saturday. (No service is operated on Sunday.) As the information in Table 3 indicates, during the baseline period of 1986, peak riders represented 49.9 percent of total riders and 50.0 percent of net riders (excluding students). A slight shift toward the off-peak did occur in two successive years. By 1988, peak passengers had declined to 45.7 percent of all riders and 46.3 percent of net (nonstudent) riders.

TABLE 3 RIDERSHIP BY TIME PERIOD

	Percent of Total Ridership		
	1986	1987	1988
Weekday			
Peak	50.2	47.3	45.8
Base	43.2	45.7	47.2
	----	----	----
Subtotal	93.4	93.0	93.0
Saturday	6.6	7.0	7.0
	----	----	----
TOTAL	100.0	100.0	100.0
Total Ridership	1,387,584	1,345,599	1,347,350
	Percent of Net Ridership *(a)*		
	1986	1987	1988
Weekday			
Peak	50.2	47.3	46.5
Base	42.4	45.0	45.6
	----	----	----
Subtotal	93.0	92.3	92.1
Saturday	7.0	7.7	7.9
	----	----	----
TOTAL	100.0	100.0	100.0
Total Ridership	826,951	1,015,838	979,255

(a) net ridership excludes students

The highest proportion of all riders (including students) in 1988 is the weekday base period. It has increased its share of all passengers from 43.5 percent in 1986 to 47.2 percent in 1988. As stated earlier, 45.0 percent of all riders in 1988 were carried in the weekday peak period. Saturday ridership rose from 6.6 percent in 1986 to 7.1 percent of all riders in 1988.

Similar proportions exist for the net (nonstudent) riders. When students are removed from the total, the peak period

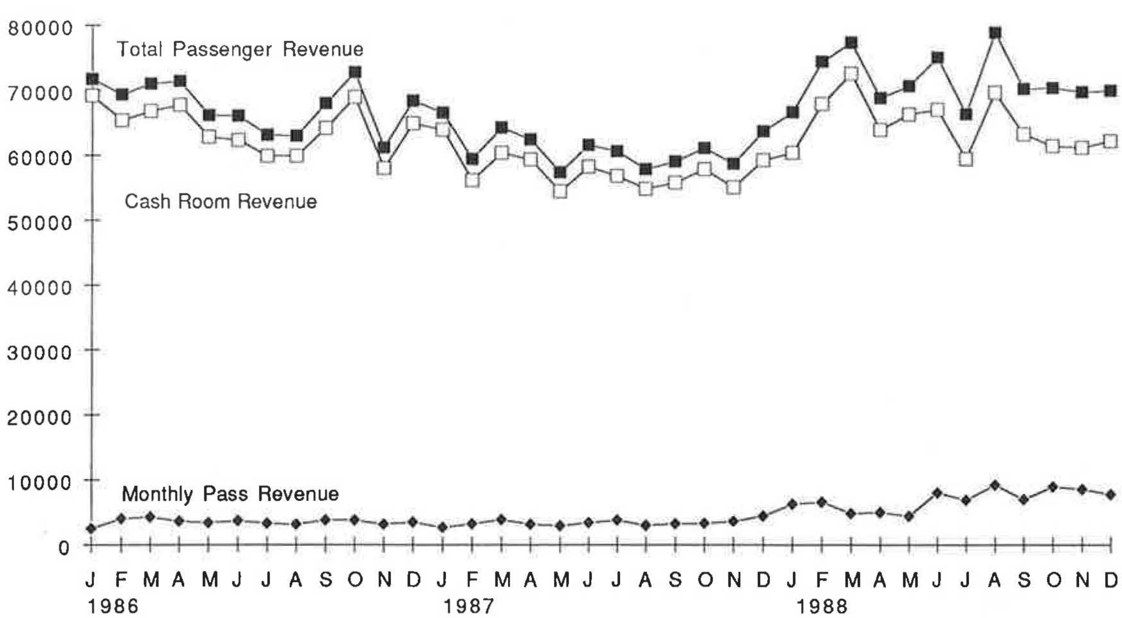

FIGURE 2 Revenue trends.

remains the highest proportion with 46.3 percent of net ridership. Weekday base-period riders are 46.0 percent of 1988 net passengers. The Saturday percentage increased from 7.0 percent in 1986 to 7.7 percent in 1988.

As Table 4 indicates, fare elasticities also can be calculated for the peak and base periods. The response to the 1987 midday fare change was in the range expected. There was no fare change in the peak period. Hence, no elasticity is reported. The 1988 elasticities are quite low, indicating that fewer people were lost to the fare increase than would be expected.

It is speculated that this apparent insensitivity to fare was in part caused by the turbulence in fares over the 3-year period. The elasticity calculated for the 1986-to-1988 fare change was in the normal range.

Period	*1986–1988 Fare Elasticity*
Peak	−0.388
Base	−0.424

Finally, the deeply discounted off-peak fares did succeed in shifting three to four percent of riders from the peak to the base period as well as in increasing total ridership for 1987 by about 2.1 percent (see Table 1). The impact of the off-peak fare reduction was an increase in ridership, all of it coming in the off-peak. As presented in Table 5, peak-period ridership declined in 1987, whereas total ridership increased.

PROPORTION OF RIDERS AFFECTED BY ZONE FARES

Fare zones were placed approximately 3 miles from the Binghamton central business district (CBD) at boundaries between Binghamton and the other municipalities in the service area. A pulse transfer system is used in downtown Binghamton, and most routes are through-routed. The CBD is not considered a zone boundary, so riders do not pay a zone charge until they cross a municipal boundary.

On average, about 35 percent of riders pay a zone charge. The distribution by time of day, determined by dashboard counts, is as follows:

TABLE 4 PEAK- AND BASE-PERIOD ELASTICITIES

Traffic Period	Fare Change Elasticity	
	1986–1987	1987–1988
Peak	–	−0.183
Base	−0.264	−0.090

TABLE 5 TOTAL RIDERSHIP BY TIME PERIOD

Traffic Period	1986	1987	1988
Peak	1,534,706	1,463,125	1,374,507
Base	1,337,870	1,459,985	1,419,622
Saturday	202,987	216,643	213,545
Total	3,075,563	3,139,753	3,007,674

Time of Day	*Percent Paying Zone Charge (%)*
a.m. peak	33
Midday	32
p.m. peak	35
Night	46
Saturday	39
System average	35

RIDERSHIP BY MONTHLY PASS USERS

It was speculated that monthly passes would become more attractive in the zone fare structure. BC Transit drivers count each time a passenger boards using a monthly pass. According to these driver counts, boardings by pass users have almost doubled since the baseline period, as follows:

Year	*Boardings by Pass Users*	*Change (%)*
1986	149,566	–
1987	175,158	17.1
1988	311,869	78.1

However, there is more than one type of pass being counted in this category. The fare changes included the introduction of a student pass and an elderly and handicapped pass, intended for those reduced fare riders who must ride frequently during the peak period. Their boardings are included in the total. By comparison, the 1986 boardings represent only adult pass users. Thus, some of the increase is attributable to the new passes.

A review of the actual number of passes sold can further distinguish these trends. The overall growth in the number of passes sold follows percentages similar to pass boardings.

Year	*Total Passes Sold*	*Change (%)*
1986	2,335	–
1987	2,991	28.1
1988	5,206	74.1

As stated, not all passes are sold to full fare riders. In 1988, adult full-fare passes were only 45.8 percent of the total of 5,206 passes sold; student passes accounted for 29.4 percent of the total; and the new elderly and handicapped pass accounted for 24.8 percent of the total.

Most relevant to the demonstration is the trend in sales of adult full-fare passes. The number of passes sold increased by 7.3 percent from 1987 to 1988. Recognizing the downturn in sales in 1987, the sales level in 1988 was 2.1 percent higher than the 1986 baseline period.

Year	*Full-Fare Passes Sold*	*Change (%)*
1986	2,335	–
1987	2,222	4.8
1988	2,384	7.3

With the expansion of the pass program has come a lower average usage rate for passes, in part a reflection of their greater use by reduced fare riders who may buy passes for convenience and not always exceed the breakeven point in the pass price. To illustrate, the 311,869 boardings by pass users in 1988 correspond to a total of 5,206 passes sold, for an average of 60 boardings per pass. This usage rate is similar to that of 1987, when a total of 2,991 passes were sold and

175,158 boardings were counted. However, in 1986, when only adult passes existed, 2,335 passes were sold and 149,566 boardings were recorded, for a rate of 64 boardings per pass.

Because a related objective is to move more passengers from cash to prepaid fares, BC Transit is succeeding. Pass user trips have increased from 5.6 percent of all revenue passengers in 1986 to 8.7 percent in 1988.

INSTITUTIONAL IMPACTS

In addition to the quantitative impacts, Broome County's new distance-based fare structure can be assessed with respect to its impact on service users and providers. These impact areas include passenger satisfaction, fare payment abuse, driver acceptance, and internal record keeping.

Passenger Satisfaction

The reaction of riders to the fare changes can be measured by two techniques—responses to the attitudinal questions on the on-board survey conducted annually during the demonstration and comments registered by individuals directly with BC Transit personnel.

On-Board Survey Results

The surveys conducted in 1987 and 1988 included questions to gauge the attitudes of passengers toward BC Transit. One of the most notable findings from the on-board survey was the change in attitudes about the fare structure. In 1987, when off-peak fares were reduced for all riders, almost 60 percent indicated they were very satisfied with the fares. Only about 5 percent were not satisfied. But in 1988, after the zone fare structure was implemented along with other fare increases, 38 percent said they were not satisfied. Only 21 percent said they were very satisfied. The balance of 41 percent said the fares were okay.

Attitude Toward Fare Structure	*Percentage* 1987	1988
Very satisfied	59	21
Service OK	33	41
Not satisfied	5	38
No response	3	–
Total	100	100

Thus, although the majority continued to give the fare structure a positive rating, the extent of the riders' satisfaction is much lower in the 1988 survey than in the 1987 survey. These results are not surprising, as the 1987 survey followed a fare decrease and the 1988 survey followed an increase.

Individual Comments

BC Transit reported that it received fewer negative comments than anticipated to the new zone fare structure. Most of the complaints were from elderly and handicapped (E & H) riders. The new fare structure eliminated a separate fare category for these riders by establishing an off-peak fare for all riders equal to one-half of the full peak fare. However, in so doing, E & H riders traveling during the peak would now have to pay the full fare, reversing the policy change in 1987 to extend E & H fares to all hours.

In response to the concerns of E & H riders who had to travel in the peak period, BC Transit added a $16 monthly E & H pass in March 1988, 2 months after the new fare structure was implemented. The pass price is high for those traveling only in the off-peak but attractive to those who make many peak trips.

In general, however, most riders understood and accepted the system's need to increase fares to generate additional revenue. The amount charged, even with zones, remains relatively low for the average rider. Further, regular riders can avoid zone charges by using passes and tokens.

Fare Payment Abuse

BC Transit reported no significant problems with underpayment or other fare-beating techniques as a result of the zone fare structure even though enforcement was by the honor system. Any payment abuse that may have occurred, therefore, fell within generally acceptable levels.

Driver Acceptance

Implementation of the zone fare structure was a smooth and orderly process. To a large extent, this is attributable to the advance planning and preparation undertaken by BC Transit. Some of the more significant activities include the following:

- Preparation of the *Driver's Manual for the Zone Fare System.* This booklet explains how and when to charge zone fares as well as how to fill out the new daily trip sheet. The manual also contains a map of each route showing where the zone lines are drawn. The manual was designed to be carried on board by the driver. In addition to receiving the manual, each driver participated in a training session on zone fares.
- Preparation of the *Passenger Guide to the New Zone Fare System.* This pamphlet presents the new fare structure, explains how the zone charges work, and shows all zone lines on individual route schematic maps. This guide was available on board buses, at BC Junction, and through BC Transit's other passenger information outlets.
- Posting of Zone Decals on All Bus Stop Signs. As part of the zone fare structure implementation, BC Transit posted a color-coded triangle on bus stop signs showing in which particular zone the stop was located. The symbols were highly visible and helped to orient riders and drivers to the zone lines. This action helped reduce potential payment disputes resulting from a lack of information.

The driver is the primary person with whom the rider interacts. In the case of a fare change, they can receive the brunt of the passengers' negative reactions. However, in this case, riders were well informed of the change and drivers had little difficulty. As a result of their training, they also were prepared to inform riders and enforce the new fares.

Recording Keeping

BC Transit's established procedures include a driver count of all passenger boardings by major fare categories. Drivers used a key pad installed on the farebox for these counts. At the end of each trip, they transfer the totals to their daily trip sheet and reset the counter.

Because these thorough procedures were already in place, only minor modifications were needed to accommodate the zone fare structure. Essentially, the counting buttons and the trip sheet columns were redefined to incorporate zone crossings. These adaptations occurred throughout all record-keeping activities for ridership and revenue reconciliation. As information is provided for each trip, staff can aggregate the results into peak and off-peak periods as well as the major fare categories. A monthly summary is prepared as part of BC Transit's routine management information reports.

CONCLUSIONS

The Broome County demonstration has shown a number of things about distance-based fares:

- It is possible to implement a zone fare system without seriously disrupting riders, drivers, or system revenue. Though there may be phase-in problems, these are overcome readily.
- The increase in total ridership resulting from an off-peak discount calculated on aggregate statistics can be expected to conform to fare change elasticities at the low end of the normally expected range: -0.20 to -0.25.
- Elasticities to fare changes implemented through zone charges are in the range expected for any fare change when calculated on the resultant average fare.
- Zone fares do not have the potential to dramatically increase revenue in a small- to medium-sized system, because only about 30 percent of the riders will pay zone fares.
- A sharp off-peak discount on the order of half-fare will shift about 3 to 4 percent of riders to the off-peak and increase total ridership slightly. Revenues will fall about 10 percent while ridership increases about 2 percent.
- Adult full-fare passengers do not increase their purchase of transit passes significantly when zone fares are introduced, even if zone fares are forgiven for pass users. An increase in pass sales did result from the introduction of new passes for students and senior citizens, which also exempted the user from zone charges.

The findings from the Binghamton demonstration indicate that transit systems of this size that adopt a policy of fare differentiation can introduce zone fares at no detriment. Modest revenue gains and ridership losses can be expected as with any price increase. However, if the system has adopted a philosophy of fare simplicity, there is no compelling reason to abandon that philosophy on the basis of these results, as the revenue impacts of zone fares were not large.

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Crisis and Recovery: Urban Public Transport in Morocco

SLOBODAN MITRIC

The developments in urban public transport in Morocco in the 1980s, with focus on the two largest cities, Casablanca and Rabat, are traced. In view of the near collapse of transport services provided by municipal enterprises in the early 1980s and their difficult financial situation, the underlying problems of infrequent fare adjustments, failure to compensate the enterprises for the low social fares of school children, and organizational rigidity inherent to the public sector, are identified. Several early propositions expected to resolve the urban transport crisis are discussed, including the market segmentation experiment introduced by the Rabat municipal transport company (the provision of seat-only, double-fare services), and plans to construct new urban rail systems in the two cities. An approach that was implemented in 1985 has become a success story in North Africa. It includes the deregulation of public transport services in Casablanca and Rabat, in which private operators are allowed to break the public enterprise monopoly, albeit only in the first-class (seat-only) market. The principal issues remaining 5 years into the experience with deregulation, notably what to do with insolvent public enterprises, how to help the private sector achieve its full potential, and how to protect the most vulnerable travelers—the urban poor—are reviewed.

Throughout the past decade, urban transport problems in the two largest Moroccan cities, Casablanca and Rabat, have attracted much attention in the professional community. The earliest interest centered on the difficulties experienced by the municipal transport companies (MTCs), which for some 20 years served the eight largest Moroccan cities, operating largely as monopolies (*1–7*). By the late 1970s, the majority of the companies were in chronically poor financial condition and unable to maintain service at past levels, much less to expand capacity to meet the increasing demand for urban travel. The second wave of research followed the 1984 decision by the Moroccan government to start deregulating this sector and the subsequent start-up of private transport operations in Casablanca and Rabat (*8–11*). Somewhat in the background, but no less real, has been yet another subject, the feasibility of rail-based systems for the two cities, addressed mainly in consultants' reports (*12–14*).

Five years into the experience with deregulation, with the private sector flourising, the authorities are on the threshold of important decisions concerning the destiny of MTCs, the expansion of private sector operations into different services and other cities, and the introduction of new, rail-based modes.

On the basis of a larger study (*15*), the preceding themes are integrated into a broader, policy-oriented picture. From the examples of Casablanca and Rabat, factors are identified that have contributed to urban transport problems in Morocco, reasons are highlighted for the demise of municipal transport enterprises, and the early experience with the new private operators is reviewed. Future directions for the development of urban public transport in the country are then outlined and discussed. The field work for the study, consisting mainly of in-depth interviews in the two cities, was carried out in early 1988; statistical data were generally those available at the end of 1986 (in Rabat) and in 1987 (in Casablanca).

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THE COUNTRY AND URBAN BACKGROUND

Morocco has about 23 million people, and expects to reach 32 million by the year 2000. It belongs to the group of lower middle-income economies (1987 GNP per capita was $620), growing at about 3 percent per annum, just above the population growth rate. After a balance of payments crisis in 1983, with foreign debt reaching about 70 percent of GNP, the country embarked on a macroeconomic stabilization program and a series of supporting sectoral adjustments. These changes have started giving positive results in terms of reducing budgetary subsidies, rationalizing public investment, and increasing exports, while controlling inflation and maintaining per capita incomes.

Moroccan cities have been growing faster than rural areas; urban population is currently 44 percent of the total and is expected to reach 50 percent by the end of the century. Much of the growth has been through in-migration from the countryside, the new arrivals settling down at the urban fringe. Casablanca, with 2.5 million people in 1985, is the dominant urban area economically, politically, and culturally. The Rabat urban area has about 1 million, and another 10 cities have populations between 100,000 and 500,000. Three-fourths of all urban jobs are in the private sector, where artisanal and commercial jobs dominate.

DEMAND AND SUPPLY CHARACTERISTICS OF URBAN TRANSPORT

Demand for travel is determined by the population growth and structure, the cultural and work habits, incomes, and urban spatial patterns. Apart from the rapid growth, two aspects of Morocco's urban population are vital for understanding transport problems here: (a) the predominance of young people (50 percent of total are under working age); and (b) the high incidence of poverty, with 28 pecent of people under the urban poverty threshold of 2,473 Moroccan Dirhams (Dh) (equivalent to $246) expenditure per person, per year. The young generate massive demand for school-related travel, while both youth and poverty lead to a powerful downward pressure on public transport fares. Average incomes are low: in 1985, an average urban household spent Dh 26,667 ($2,650) and the minimum guaranteed monthly wage was about Dh 820 ($81). Consequently, car ownership rates are low as well—about 50 cars per 1,000 population in larger cities, and 20 to 30 cars per 1,000 population in smaller cities. The local life style, with its habitual two-shift work and school day, poses a heavy load on the urban transport system.

Moroccan cities are characterized by two centers that typically coexist side by side: the traditional médina, with high population densities and narrow, meandering streets fit mostly for walking, and the modern downtown, with its high-rise commercial buildings and rectangular grid-type street networks. These centers generate strong radial demands, easy to serve by public transport in smaller cities; as the cities expand, the lower-income residents and newly arrived migrants who dwell in peripheral communities find their center-bound trips increasingly long. Industrial estates, located away from downtowns, pose a different problem, that of interperipheral connections for industrial workers.

Because a great majority of people (80 percent of households in Casablanca) do not own cars, the brunt of the demand falls on public transport, two-wheel vehicles, and walking. Surveys carried out in the 1975–1980 period indicated that walking accounted for a large proportion of daily trips, between 50 percent in Casablanca and 84 percent in Tangier (*1*). The modal share of public transport was modest, 30 to 35 percent of nonwalking trips in larger cities and approaching 50 percent in smaller ones. Two-wheel vehicle share was important at 26 to 27 percent of nonwalking trips in the largest cities, and up to 66 percent in Marrakech. Altogether, the mobility rates were low (0.95 nonwalking trips per person per day and less, depending on the city), reflecting suppressed demand for travel. The key factors underlying the situation included a low supply of conventional public transport services (prevailing until the mid-1980s), relatively high fares, and the untapped potential of paratransit modes (taxis and various types of small, shared vehicles).

From 1964, when the first MTC was created in Casablanca, until 1985 when private companies were reintroduced (again in Casablanca), MTCs were basically the monopoly providers of conventional transport services in eight major cities. Neither in the 1964–1979 period, when they were covering their costs, nor in the post-1979 period, when the majority of MTCs were in a difficult financial position, did the supply of services approach reasonable levels. In larger cities, ratios of 4,000 to 6,000 inhabitants per bus in circulation prevailed, against a modest norm (adopted by the Government) of one standard-sized bus for each 3,000 inhabitants.

With the exception of schoolchildren and several categories of state employees who pay sharply discounted fares, regular passengers pay fares that are far from low relative to their incomes, especially when their daily work journey requires transfers. On the basis of Casablanca data from 1985, minimal travel requirements would take about 11 percent of revenues for urban households at the 30th percentile, but about 30 percent for families among the poorest 10 percent. A person at the poverty threshold would spend about 24 percent of his or her expenditures on bus fares.

Paratransit modes, widespread in many large cities of the developing world as cheap and efficient alternatives to conventional public transport, are largely absent in Morocco. Even the most accepted among paratransit modes, the taxi, is in short supply because of tight regulations that limit market entry and impose low fares. If the definition of paratransit is stretched somewhat, then one of its forms has been flourishing: the transport for own-account. These are bus fleets operated by government agencies and other large employers for the benefit of their workers.

SECTORAL INSTITUTIONS

As the patron of local governments in Morocco, the Ministry of Interior (MOI) has a comprehensive, supervisory authority over urban transport, both functional and financial. This authority extends over all activities of MTCs, the taxis, traffic management, police, and urban planning. The Ministry of Finance (MFIN) exercises a strict accounting control over MTCs (a priori permissions even for the smallest payments are required, in addition to normal audits), but apparently does not get involved in policy. Interventions of the Ministry of Transport (MTR) are limited to the intercity network and stop at the city gates.

The purview of the MOI includes the creation of MTCs, appointment of their managing directors and members of the board, approval of operating budgets and investment plans, and authorization of fare changes. MOI also grants operating and capital subsidies, and helps to arrange loans through the Fonds d'Equipements Communal (FEC), a public infrastructure fund lending to local governments and their agencies. Within the MOI, an urban transport division, located within the directorate for municipal companies and franchises, is responsible for MTCs. This division collects and analyzes operational and financial data of MTCs with reasonable efficiency, but lacks both the capacity and the mandate to develop policies and lobby for their adoption by the decision makers.

At the urban area level, the government is organized in two interweaving branches: (a) provincial, representing the national government and headed by officials appointed by the MOI; and (b) municipal, locally elected. A province typically covers several urban areas (in addition to rural municipalities). Only the agglomerations of Casablanca and Rabat are large enough to have their own provincial governments, Wilayas (corresponding to French préfectures); a corresponding elected body for these agglomerations is made up of elected officials of their constituent municipalities. For all practical purposes, major administrative and technical functions are in the hands of the provincial governments. In matters related to urban transport (as in all other sectors), the Wilaya officials (governors, secretaries-general) execute policies adopted by the MOI. The role of elected officials in urban transport appears to be limited largely to demands for route and service changes. A process of decentralizataion is underway in which financial resources and the decision-making power are being progressively shifted from the national to local governments, which at present dispose of only 5 percent of all public expenditures in Morocco. One of the major stumbling blocks in this process is low technical and managerial capacity of the municipalities. In the field of urban public transport and traffic management, this capacity is minimal at present not only in smaller cities, but even in the largest ones.

DIMENSIONS OF A CRISIS: MUNICIPAL TRANSPORT COMPANIES

Eight MTCs employ more than 7,000 people, carrying more than 1 million passengers per day, and bring in about Dh 433 million (U.S. $48 million) in revenue per year (Table 1). According to size, they fall into three groups: Casablanca leads with 380 serviceable buses (of which 320 are in circulation; Rabat follows with 176 (about 150 in circulation, of which only 81 are standard buses); Fez is close with 150 buses (110 in circulation); and the remaining five are small with 27 to 73 buses (20 to 60 in circulation). Most of these companies once operated larger fleets: Casablanca had about 550 buses in 1982 (452 in circulation) and Rabat had 185 buses in 1983 (176 in circulation, of which 150 were standard buses).

Judged in terms of fleet and staff productivity, some MTCs (Fez, Marrakech, and Agadir) perform reasonably well, with annual trip lengths falling between 77,000 and 95,000 km per bus in circulation, and daily loads exceeding 1,200 passengers per bus. They employ between seven and eight staff per bus in service, which is on the high side but acceptable for firms with a low level of outside services. The proportion of active fleet that is in daily circulation exceeds 85 percent, suggesting effective maintenance services. Other MTCs are not doing as well—some are evidently overstaffed (13 employees per bus in circulation in Tangiers; 10 in Casablanca, Rabat, and Meknes), or have inefficient maintenance departments (only 59 percent of the active fleet circulates in Tangiers). In four companies, the number of passengers per bus-kilometer exceeds five, indicative of severe bus overloading. Still, with the exception of Tangiers MTC, which has clearly inferior results, these companies show positive results in at least some dimensions of performance.

Since the late 1970s, MTCs have suffered from chronic financial difficulties. Only two (Fez, Agadir) have consistently managed to cover their total operating costs from fare revenues. At the other extreme, Rabat and Tangiers have yet to meet their direct operating costs. The remaining four often covered their direct costs, but rarely, if ever, covered the total. The long-term impact of operating losses is reflected in the debt-assets ratio. Of the four largest companies, three have debts substantially larger than the value of assets (155 percent in Casablanca, 175 percent in Rabat, and 191 percent in Marrakech); smaller companies, with the exception of Agadir, do not fare much better. In 1986, the total accumulated debt was about Dh 340 million. Short-term debts account for between 60 and 100 percent of the total debt, a sure sign of unresolved financial relations at the policy level.

The lack of financial capacity has been the prime factor behind the failure of MTCs to renew, much less expand, their fleets in the face of growing demands for transport. On the service side, this problem has resulted in excessive waiting times, overcrowded terminals and buses (sometimes with loads higher than 150 passengers), and ticket fraud. Other impacts include a shift to other modes and walking, and a loss of mobility, particularly serious in large cities. The negative impact of all this on living standards and access to jobs for individuals, as well as aggregate costs to the urban economy in terms of diminished productivity and sheer time lost, while incalculable, is likely to be enormous.

Causes of Deficit

Behind the operating losses of MTCs lie intertwined problems both on the cost and revenue sides. The following account is based on a review of the two largest MTCs, in Casablanca and Rabat. Bearing in mind the pitfalls of making international comparisons even with better data than available here, average costs (per bus-kilometer) of these two companies appear to be two to three times higher than in many companies in Africa and Asia, and have a ratio of about 1:2 to costs of bus companies in French cities (with the ratio of GNPs for the two countries being 1:13) (*16,17*). The underlying problems, on the cost side, are as follows.

1. First, there were problems caused by the nature of the administrative system to which MTCs belong. Like all public enterprises in Morocco, MTCs have operated in a highly constrained organizational environment. The degree of outside control has been overpowering and, conversely, the management has had a narrow maneuvering space and little accountability. The MOI controlled investments, fares, and higher-level appointments; local authorities imposed route and service policies; the MFIN controlled all expenditures with ex ante, in addition to ex post, audits; the Ministry of Industry controlled both local purchasing and imports.

2. Second, there have been problems related to personnel. The staff of MTCs have enjoyed a status akin to that of civil servants, with salaries and benefits superior to those of most bus passengers. Labor costs accounted for about 40 to 50 percent of operating costs, high for a low-income country. Past hiring practices were not always motivated by enterprise needs. Once employed and past a probation period, employees could be fired only for serious refractions of duty. This made it impossible to reduce staff in parallel with fleet reduction, or as an austerity measure. The promotion system was based largely on seniority. All this has led to overstaffing, and a work force both laden with long-time employees and short on skilled workers and experienced managers. Difficult operating conditions, a drop in salaries in real terms in the 1980s, and a general erosion of the MTC status have all contributed to low staff morale, absenteeism, vandalism, and poor productivity. Casablanca and Rabat MTCs use 130 to 140 staff to produce 1 million bus-km, compared with 60 staff for better companies the world around (*18*). (However, Fez, Marrakech, and Agadir MTCs are much better at 80 to 90 staff per 1 million bus-km).

3. Third, the continuing deficit itself has acted to increase operating costs. The shortage of investment funds meant that buses were used beyond their economic life; severe overcrowding also increased the rate of breakdowns (in addition to losses of revenue caused by fraud). Maintenance tools and materials could not be replaced or modernized, and data processing equipment and productivity-aimed technical assistance could not be purchased. Difficulties with buying spare parts has immobilized many buses for long periods of time,

TABLE 1 PRINCIPAL MOROCCAN CITIES AND THEIR PUBLIC TRANSPORT ENTERPRISES

POPULATION/AUTO OWNERSHIP	Casa	Rabat	Fes	Marrak	Meknes	Tanger	Safi	Agadir
1985 Area population (000)	2456	1018	483	472	338	298	208	120
1985 Auto registrations (000)	132	54	12	12	10	13	5	6
PUBLIC TRANSPORT COMPANY DATA								
Year of creation	1964	1965	1971	1968	1968	1965	1977	1976
Annual passengers (mill)	200	61	61	24	20	8	10	27
Daily passengers (000)	549	168	167	65	55	22	27	73
Active fleet (buses)	380	203	150	60	55	27	42	73
Buses in circulation	320	146	110	53	41	16	36	62
Annual (million) kms run	23	11	9	5	3	1	2	6
Staff	3238	1470	758	448	397	209	244	477
Operating revenues (Dh million)	202	69	55	28	20	9	12	38
Operating costs (Dh million)	199	84	51	28	22	11	13	38
Total assets (Dh million)	128	60	na	8	10	5	7	10
Total debt (Dh million)	198	104	na	15	9	4	7	3
Short-term debt (Dh million)	110	62	na	12	9	2	3	2
RATIOS								
Autos/1,000 population	54	53	25	25	30	44	24	50
Population/PTC bus in service	7675	6973	4391	8906	8244	18625	5778	1935
Passengers/Bus-kilometre	9	5	7	5	7	7	5	5
Daily passengers/bus in service	1715	1148	1522	1222	1346	1353	762	1181
Buses in circ/Active fleet(%)	84	72	73	88	75	59	86	85
1,000 km/bus in circ/year	72	77	84	95	74	70	62	89
Staff/Bus in service	10	10	7	8	10	13	7	8
Staff/Million bus-km	140	131	82	89	131	187	110	86
1,000 passengers/staff	62	42	81	53	51	38	41	56
Revenues/costs(%)	101	81	107	100	92	80	95	101
Average costs (Dh/bus-km)	8.6	7.5	5.5	5.6	7.1	10.1	5.9	6.8
Average revenue (Dh/passenger)	1.0	1.1	0.9	1.2	1.0	1.1	1.2	1.4
Total debt/assets (%)	155	175	-	191	85	74	93	30
Short term debt/total debt (%)	55	59	-	80	100	59	42	62
Year to which data apply	87	86	86	85/86	85/86	84/85	85/86	85/86

Notes:

(1) When a bi-annual period is given in the last row, generally the balance sheet alone is from the earlier year. Year-to-year variability is considerable.

(2) For orientation, the average exchange rate per US$ was Dh 9.10 in 1986 and 8.36 in 1987.

or permanently. MTC Rabat is a striking example of this with a book fleet of 299 buses, of which only 176 are active. Finally, the lack of working capital pushed MTCs to rely on short-term loans, whose higher interest rates provided an extra push to cost escalation.

On the revenue side, the generic reason for deficits has been the failure of the government to pay full compensation for various constraints imposed on MTCs for social and political reasons. To start with, regular (nondiscount) fares were kept at levels that did not reflect costs. The government infrequently gave approval to increase fares (five times since 1965 in Rabat), allowing revenues to fall far behind in real terms (*6*). This policy was particularly serious at the time of the second oil price shock of 1977–1980, and the related increase in the world prices of industrial products to which bus companies are particularly sensitive. When approved, the scale of fare increases was at times so high (40 to 43 percent) that it led to substantial losses of patronage (and revenue).

The second major constraint on the revenue had to do with the so-called "social" fares. Several categories of passengers have benefitted through free rides or inexpensive passes. In Rabat in 1986, subscribers accounted for about 29 percent of all trips, but only for 6 percent of revenue; in Casablanca (in 1987), the corresponding numbers were 19 and 4 percent. Even if the passenger statistics are not fully credible, these ratios reflect an actual average fare that is devastating for the finance of MTCs. The situation has deteriorated even further with the recent flight of regular-fare passengers to private operators. The largest group among the privileged are schoolchildren and university students. In Casablanca in 1987, monthly passes for unlimited rides cost Dh 40 ($4.78) for schoolchildren and Dh 50 ($5.98) for students (doubled in 1986, a first increase for this pass in many years). With conservative assumptions on trip frequency (even without counting the transfers), this amounts to a discount of about 64 percent off Dh 1.20 ($0.14) for the cheapest regular ticket. The corresponding compensation, had the government paid it, would have amounted to about Dh 14.6 million ($1.75 million), higher than the most historic deficits of the company.

The subsidies actually received by MTCs did not bear any relation to losses from various constraints on fares. In this light, the cross-subsidy from regular-fare passengers to discount-fare passengers has been enormous; this largely explains why regular fares have been high enough to be onerous for lower-income people, while at the same time failing to cover operating costs of MTCs.

The Rabat company has received about Dh 30 million since 1977, mainly in the form of capital grants to purchase equipment. (The exchange rate to the U.S. dollar was Dh 4.50 in 1977 and Dh 8.36 in 1977.) Compare this subsidy to the company's accumulated debt of Dh 105 million ($11.5 million). Casablanca, with its greater size and a debt of about Dh 200 million ($23.9 million), received relatively less help, about Dh 17 million capital grants and about Dh 26 million in operating subsidies, all of these in the 1980–1982 period. It is not clear whether the government was unable to contribute more, or the MOI was not strong enough to win enough support for MTCs in interministerial budgetary battles. In any case, no direct subsidies were given after 1982, this being a period of intense budgetary crisis in Morocco.

In addition to capital grants, loans from the FEC could be considered as aid, because they were given to companies that were clearly not creditworthy. Data from the 1976–1987 period for Casablanca MTC indicate that the FEC was the main source of investment funds at 65 percent, followed by equity funds at 26 percent and Government grants at 9 percent. When MTCs fell back in loan repayments in 1982, the FEC stopped granting them further loans until 1985, when the decision to reintroduce private operators was accompanied by a fare increase for the MTCs, and some new loans by the FEC were authorized.

Financial aid in the form of capital grants and loans was not enough to permit the MTCs to renew and expand their fleets and support facilities. Because there were no operating subsidies, MTCs dealt with working capital shortages by taking short-term loans and using practices normally considered illegal: failing to pay suppliers of goods and services, social security contributions, taxes, and insurance premiums. For Casablanca, the last two categories accounted for 60 percent of the short-term debt in 1987. This is a particularly inefficient form of covert subsidy, creating a complicated web of arrears and contributing to erosion of the overall financial discipline in the public sector.

Prederegulation on Attempts to Resolve the Urban Transport Crisis

The list of ideas and approaches used or just considered by the government of Morocco to resolve or at least lessen public transport problems of the country's large cities, before embarking on the deregulation, would have only two significant entries. One of these, the introduction of first-class services in Rabat MTC, was actually implemented. The other entry, making large-scale investments in new transport technologies, has been intermittently considered but never acted on.

First-class services of midsize buses operating in seat-only mode at fares roughly twice the regular fare were conceived by the management of the MTC Rabat as a way of bypassing the blockage of social fares for their standard services. The underlying assumption was that many passengers would both be able and willing to pay higher fares for better services. The revenue from these new services was expected to cover their operating costs, with enough to spare to cross-subsidize regular services. Starting with 40 minibuses at the end of 1984, first-class vehicles grew rapidly to become 46 percent of the fleet owned by the MTC Rabat by the end of 1986. The impact of first-class services was considerable: already in the first year of operation, there were 4.5 million first-class trips compared with 69 million trips for regular services. In 1986, when the patronage of former services collapsed to less than 36 million full-fare-paying passengers, first-class service climbed to nearly 8 million. If any profits were made, however, they were not used to support regular operations but to expand further the first-class services. Thus, improved service for better-off passengers was achieved only at the cost of further erosion of service for regular passengers. This experiment in market segmentation provided precious experience for the coming deregulation of the sector; it would be bitterly ironic if, in the longer run, it also destroyed the survival chances of MTC Rabat.

The other significant approach proposed, investing in new transport technologies in the two cities, derived its inspiration from the evident lack of capacity and low travel speed of MTC bus services (*12–14*). In a common misreading of a policy problem as a vehicle technology problem, it was believed that rail-based systems would correct both of the earlier shortcomings. Of the three most recent proposals, two included light-rail lines for Casablanca and Rabat, and the third involved a rapid transit system for Casablanca. The envisioned lines were 13 to 15 km long; light-rail alignments were mostly at grade, whereas the rapid transit proposal combined underground, at-grade, and elevated sections. Capital costs of the proposed systems ranged from $150 million for the light-rail to $300 million for the rapid transit. The peak-hour patronage forecast for the 1990s was of the order of 8,000 to 10,000 passengers. The consultants estimated that fares similar to those then charged by MTCs would suffice to cover direct operating costs of these new systems.

The government has not acted as yet on any of these proposals, probably because of high capital costs and low passenger volumes forecast by feasibility studies. The projected capital costs of several hundred million dollars would be substantially higher than anything the government had invested in urban transport over the previous two decades and financing would be a major issue as well. Peak demand forecasts under 10,000 passengers per hour must have come as a disappointment and a surprise to the authorities, given severe overcrowding of buses witnessed daily on the streets of Rabat and Casablanca. It is understood that yet newer proposals for a metro in Casablanca have been put forward since 1988; that an attractive financing package might emerge in tandem with a study whose cost estimates would be low enough and patronage forecasts high enough is still possible.

RECOVERY: DEREGULATION IN CASABLANCA AND RABAT

The return of private operators to the two major cities, announced in mid-1984, should be seen as part and parcel of the macroeconomic stabilization program and the reform of the public enterprises undertaken at that time. The process of deregulation was carried out at an unprecedented speed, reflecting a firm commitment by the authorities to this option—private services to be started in Casablanca already by July 1985 and in Rabat by March 1986.

Companies with appropriate technical and financial references were invited to bid for first-class services on existing MTC routes. Vehicles were limited to 25-seater buses, or larger. Each bidder was to propose the minimum-sized fleet to be placed in service, allowing at least 20 percent reserve. Line frequencies and time tables were also to be submitted for approval by the local authorities (the Wilaya). Bidders were invited to propose fares for each line, an annual concession fee, and formulas for the revision of fares and fees, with a proviso that these would be "homogenized" over the service network.

Five companies were initially authorized in Casablanca (increasing to eight by 1988) and six in Rabat. Awards were made for groups of service routes, in an attempt to mix and match routes with high and low passenger demand. Only one company was awarded a contract for any one route (in addition to MTC services), though the terms allowed a possibility of award to third parties. Initial authorizations were made for about 150 buses in each city (compared to MTC fleets of 150 in Rabat and 320 in Casablanca). Special permits for importing buses were granted to the new operators. The adopted fares were equivalent to first-class fares (Dh 2.2) charged by the MTC Rabat. The concession fee adopted in Casablanca was variable and equal to 5 percent of traffic revenues, requiring that private operators turn in their accounts to local authorities. After indications that a variable fee would pose an enforcement problem, a flat concession fee of Dh 15,000 per line was used in Rabat. Contracts included a fare revision formula: fares could be revised annually, following an operator's request, provided that the increase calculated by the formula was 5 percent or higher.

Some of the entrepreneurs came from within the passenger transport profession (intercity or tourism). Others were freight carriers or had some relation to transport (e.g., bus manufacture). The remaining private bus operators came from fields like insurance and had no experience in the sector, but were accepted for their ample resources and good standing in the business community. The sources of financing were equally as diverse. Commercial banks were initially reluctant to get involved, thus forcing bidders to rely on equity funds only. This limited access to the market to large, well-to-do companies. Family-owned equity played an important role in Rabat as well, but by that time the business community assessed their risks to be lower and decided to participate, which permitted a mixture of suppliers' credits, commercial bank loans, and leasing credit. The decrease in risk estimates was considerable, causing interest rate to fall from 27 to 14 percent (*19*).

There has not been any formal monitoring of the costs and benefits of the deregulation. But, on the basis of circumstantial evidence, the whole experience must be judged an overall success. The growth in the private fleet has been impressive. By the end of 1987, about 200 private buses were operating in Rabat and 520 in Casablanca, up from initial levels of about 150 in each city. When added to 150 and 320 MTC-owned buses in Rabat and Casablanca, respectively, the government's supply target (one bus in circulation for each 3,000 people) was reached, even without counting buses for own-account transport. The picture is, of course, less impressive when seen in terms of passenger spaces, because many private buses are midsize and standees are not allowed. Still, service availability and quality have improved visibly, even on MTC buses. The worst of the waiting lines have disappeared from streets and terminals (*8–10*). Concerning the market share of the private operators, a recent lower-bound estimate for Casablanca, based on revenues reported for tax purposes, is about one-third (78 million passengers in 1988 versus 185 million carried by the MTC (*20*).

The principal beneficiaries of the deregulation on the demand side include all passengers who could afford to switch to first-class services. Evidently, many inhabitants of the two cities could and did. Some among them, though, might have preferred to use improved regular-class services, at fares somewhere between the first-class and the current regular fares. The same may be true of many passengers who remained on MTC buses and who, after the initial relief, are seeing their benefit dwindle. Finally, there has been little relief to passengers to whom prevailing regular fares have been onerous or unaffordable.

In addition to undisputable benefits to first-class passengers, other benefits of the deregulation have accrued to the national economy: first, the resource mobilization involved about Dh 450 ($45) million invested in fleets by the private sector (an order-of-magnitude estimate made by this writer), releasing public resources for other uses; second, there has been a reduction in demand for public subsidy, because a large proportion of urban travel is now carried under market conditions; third, some 4,000 new jobs have been created; and fourth, the government has new fiscal revenues from fees and taxes. Finally, the urban transport business must have been profitable to private operators, seeing their numbers multiplied so quickly.

What has been the impact of private competitors on the MTCs? Answers appear to differ considerably from one city to the other. The following statistics illustrate this, but much caution is warranted—the noise caused by a fare increase in August 1986; MTC fleet constraints, especially important in Rabat; and brevity of the adjustment period must be remembered. In 1985, MTC Rabat carried 75.7 million trips, of which 5.2 million were in first class vehicles; in 1986, when private companies operated only three quarters of the year, the total declined by 19 percent to 61.2 million. Changes by market segment varied widely: first-class trips increased from 5.2 to 7.9 million (a 34 percent increase, fueled by a 47 percent increase in fleet and a 38 percent increase in kilometrage). The standard passengers at regular fares declined from 52.1 to 35.7 million (a loss of about 32 percent), whereas traffic of monthly pass holders lost about 4 percent. The fleet in circulation has sunk to 149 buses (in 1986) of which only 81 were standard buses (compare to 149 such buses in 1983). Revenue fell by 5 percent and costs grew by 3 percent, despite a hiring freeze that kept the staff under the 1982 level; the resulting operating deficit was a historic high of Dh 15.7 million. At the end of 1986, against current assets of Dh 8.9 million and fixed assets of Dh 50.6 million, the company owed Dh 104.5 of which 59 percent was accounts payable and short-term debt. Arrears owed the FEC (Dh 18.1 million at the end of 1987) were the largest of all municipal company debtors. The large negative difference between current assets and current liabilities explains why MTC Rabat has difficulties meeting its salary obligations and has stopped preventive maintenance. In short, this operator is ailing.

MTC Casablanca has weathered the entry of private operators differently. Following the initial 13 percent loss of passengers in 1985 (also affected by a 43 percent fare increase in 1984), all passenger categories increased in Casablanca in subsequent years, but more so in the social fare category (24 percent since 1984). Total traffic in 1987 is still about 9 percent less than in 1983, but at a different level of supply. Space on public buses, vacated by people transferring to first-class services, is evidently being filled by new passengers paying regular fares and by increased travel of monthly pass holders. With traffic on the upswing and boosted by two successive fare increases, the revenues posted a record Dh 200 million in 1987. Unit costs fell in nominal terms, a result of higher productivity (daily kilometers per bus went from 160 to 197; fleet availability went from 72 to 84 percent; kilometers run per staff went from 6,698 to 7,123). After 10 years of operating losses, the company posted a surplus in 1987. Fare increases and fresh FEC loans in 1985 and 1987 helped, but did not account alone for this turnaround in Casablanca, as the Rabat experience demonstrated. The competition seems to have been a shot of adrenalin to the MTC Casablanca management, and they tried to compete as best they could within the narrow confines of local and national government regulations imposed on this sector: they evidently both had good ideas and the courage to implement them.

Among problems encountered so far, some are not unusual in a transition period (which does not make them any less serious) and others reflect the speed with which the whole process was implemented. Complaints against private operators center on violations of service agreements—examples include overserving profitable routes, underserving lower-volume routes, leaving terminals only when full (rather than according to schedules), not following agreed routes and stops, and accepting standing passengers. To the MTCs, this is "disloyal competition," particularly ungrateful in view of generous technical assistance provided by MTC Casablanca to help the new companies in the start-up (*11*). The downside of greater staff productivity (and lower pay) of private operators has been reckless driving of private buses, resulting in 455 accidents involving private buses in Casablanca in 1987. Overlapping service routes in Casablanca caused numerous conflicts among private operators, a problem avoided in Rabat by a more careful parceling of routes. On the administrative side, problems arose in connection with the stipulation that private operators should submit their accounts for review by the local government and with the ex post imposition of an administrative tax in addition to the agreed concession fee. Income tax collection has also been a problem, but this is not specific to the urban transport sector.

CONTINUING TOWARD RECOVERY

Three sets of interrelated issues loom large at the current crossroads in the evolution of Morocco's urban public transport. The first set is demand related, concerning diverse subgroups of public transport users and would-be users, particularly lower-income travelers. The second set refers to urban public transport modes, their organization, ownership, and technology. The third set has to do with government institutions in the sector.

Demand Aspects

If it is accepted that the problems of better-to-do public transport passengers have been resolved in a lasting manner, passengers remaining on MTC buses and those who are only latent travelers are still awaiting better days. Whether ticket-paying or pass-holding, MTC clients have become somewhat better off as a result of deregulation, but their benefits may dwindle quickly in the absence of a quick action to rehabilitate MTCs. Already these passengers face a decreasing supply of services (particularly in Rabat), and at fares that may claim a significant portion of earnings for some people. With an increasing proportion of MTC trips belonging to groups paying social fares, passengers paying regular fares can only expect their fares to increase, even if services deteriorate. Moreover, as evident from considerable losses of patronage following fare increases, the existing regular fares are entirely out of reach of some segments of the population.

Also, as noted earlier, some passengers who have shifted to the first-class services would probably prefer using better-quality services of the regular type (standing permitted). All in all, like everywhere else in the world, strong demand for improved regular services at affordable fares must exist in Casablanca and Rabat. The question is: Who is going to supply these services, the public or the private sector? An alternative way to pose this question would be this: What can be done to enable the lower-income strata to pay the level of fares necessary to finance reasonable services?

The problem of affordability is difficult to assail from the demand side. One short-run option that could be explored is that of introducing a system of targeted subsidies for the truly needy segments of the population, the hope being that the elimination of indiscriminate subsidies would take some pressure off of fares. Also in the short run, the adoption of a single-shift day for school and work would reduce the need to travel in the peak. In the longer run, the hope is that economic development of Morocco, particularly employment creation programs, will go on increasing the minimum incomes, thus lifting the affordability threshold for travel. Also, the ongoing improvements in zoning and other aspects of urban planning decisions may result in land use decisions that would reduce journey lengths for some disadvantaged urban residents.

Developments on the Supply Side

In contrast to the demand side, options in the realm of urban transport modes are numerous and promising. These are reviewed according to a mixed ownership and technological classification: MTCs, private operators, services for transport on own-account, paratransit modes, and new technologies.

What to Do with MTCs

The destiny of MTCs is a central issue. Most of them are insolvent, underequipped, and overstaffed. There are large economic and social costs tied to the continuing existence of MTCs in their current state. Yet, they perform a valuable service for the mass of population, make social objectives (arguably) easier to achieve, own considerable fleets and facilities, and employ thousands of people. Three broad evolutionary options for MTCs stand out: restructuring under public ownership, divestiture, and a mixed-ownership approach.

Restructuring Under Public Ownership Restructuring under public ownership would include writing off public debts of MTCs and reprogramming their other debts; agreeing on a mechanism through which the Government would compensate the companies for the imposition of various socially and politically inspired constraints (notably those imposed on fares); setting up productivity targets to minimize the link between subsidies and inefficient operation; and adopting development plans for MTC organization, staff, methods, and physical assets. The programs for individual companies would be documented in performance contracts, signed by the MOI and the company management. In parallel with company-based actions, a regulatory overhaul would be undertaken to increase the commercial independence of MTCs as a group. The positive aspects of this approach include the retention of a strong public voice in service policies of MTCs and the lowest transition costs (e.g., minimal staff reductions). On the negative side, the national budget might be unable to provide funds needed to rehabilitate and upgrade MTCs in financial and physical terms, and to pay regular subsidies, unless a drastic change in priorities occurs. Even if the funds were forthcoming, the probability that the public sector could ever post significant productivity gains may be low. Also, institutional capacity and discipline needed to prepare and implement the necessary reforms would be considerable; the risk is that reform would get bogged down and never achieve its objectives.

Divestiture This approach would mean turning urban public transport over entirely to the private sector, using a tendering approach already tried in Casablanca and Rabat, with the Government retaining only a supervisory role to maintain a market environment and to ensure that social objectives are achieved. This approach would involve selling the plant and equipment of MTCs to private buyers and using the proceeds to settle the MTCs' outstanding debts. The major problem with this approach would be high, possibly prohibitive social and political costs of laying off MTC employees; no precedent for this course of action exists in North Africa. Otherwise, this approach would make the lightest claims on public funds in the short run, because only modest one-time expenditures would be needed for debt settlements in excess of what the sale of MTC assets would bring. The private sector would bring a promise of considerably lower production costs, thus potentially better services and lower fares for all types of services. The flip side of the coin has increased risks of cartelization and neglecting social objectives. The monitoring effort to ensure that rules of the game are followed would be costly to organize and difficult to sustain. The success or otherwise of this approach (and of the current partial deregulation) would hinge on the freedom of private operators to set fares, though this issue cannot be avoided under any option, including the continuation of the status quo. The dangers involved with controlled fares have been illustrated earlier. The risk with deregulated fares would be that, at worst, lower-income strata might be priced out of the public transport market altogether, especially on low-volume routes. (Should this happen, the Government would have to provide direct subsidy to affected groups and subsidize operations on low-volume routes, but with competitive awards of service, as in the United Kingdom). The issue is, of course, to steer a prudent course between the Scylla of affordability for passengers and Charybdis of financial viability for operators.

Restructuring of MTCs with Mixed Public-Private Ownership This approach would be a compromise in which the private partner would bring in funds and expertise in exchange for guaranteed profits and managerial fees. The Government would retain a direct presence in service and fare decisions, and staff reductions would be minor. Difficulties should be anticipated in finding investors under this approach, the risk being that social policies and budgetary responsibilities would be handled by different parts of the Government, casting doubt over the received financial guarantees.

Future of Private Operators

Assuming that coexistence of private entrepreneurs and MTCs would continue, many of the current problems are a matter for fine tuning. Of the truly vital issues, two were mentioned under the divestiture option above, i.e., how much free rein would be allowed in fare setting and would the public authorities be able to supervise the adherence to service agreements. The fare issue will be tested soon, in view of the forthcoming overhaul and replacement decisions of the private sector. A major longer-run question for private operators concerns the expansion of their services into the regular (as opposed to first-class) market. This process would bring them into direct competition with MTCs, as well as among themselves.

Paratransit

Certain forms of paratransit are too well developed in Morocco, whereas others are developed poorly or not at all. Own-account transport services belong to the former group, likely the most expensive public transport mode in Morocco. If the Government wishes to subsidize its employees, this should be done at least cost. Taxis and diverse flexiroute arrangements, using minibuses and large automobiles, belong to a group not only neglected, but downright repressed; opportunity costs of this policy must be large, both in transport service and the employment dimension. Paratransit is the ultimate market mode in urban transport, in the sense that it is adaptable to a wide range of services and at a variety of prices (and thus to a corresponding range of incomes). The evidence is convincing that people in cities that permit and foster paratransit alongside the conventional public transport modes enjoy much higher levels of personal mobility than where paratransit is absent (*19*). A deregulation of this mode is thus long overdue.

Rail-Based Transport Modes

When they operate in a protected right-of-way, these modes have greater capacity, travel speed, comfort, and safety than the conventional street bus operations. They can also have real and beneficial, but difficult to measure, impacts on urban life and growth. Under certain conditions of construction costs, operating efficiency, and patronage, they can come close to being economically and financially viable (*21*). It does not appear that enough of these conditions could be met at present in Casablanca and Rabat, particularly not the patronage and fares needed for a reasonable recovery of costs. Moreover, impacts of a new metro or a light-rail system therein would be limited to one or two major corridors; problems with the MTCs and, generally, problems caused by inadequate sector policies, would remain. Only the stakes would be higher. These sophisticated systems themselves would require efficient organization and management to achieve their full potential. Otherwise, because of their considerable investment costs, they would end up creating even greater losses than has been the case with MTCs. Two possible counterarguments to these would be that (a) the magnitude of investment in rail technology would impose its own discipline on the policy process and contribute to the resolution of the long-standing tug-of-war between social objectives and budget realities in Morocco; and (b) rail-based projects would seem important enough to reclaim major city streets from the general traffic and reserve them for public transport vehicles only (as was done in Tunis). Both counterarguments imply that large-scale investments should be used as means of changing public policies (concerning transit fares or exclusivity of the street right-of-way). This being both a risky and a poor use of scarce capital, large-scale investments should not be seriously considered in Moroccan cities before other reforms have brought a measure of steady-state viability into public and private sector urban transport operations.

The Institutional Dimension

Considerable institutional capacity would be required to guide the evolution of the urban public transport sector in Morocco through policy and investment options outlined earlier. The history of MTCs demonstrates that past public policies and actions have been neither consistent nor comprehensive. The consistency has been most conspicuously absent in the area of fare setting and the related compensation. As for comprehensiveness, whole areas of intervention (traffic and parking management, automobile registration and taxation, staggering of work hours, using one-shift school days) have been hardly touched, or not at all. Some of the difficulties reflect a government with a broad scope of interest, to the detriment of the managerial prerogatives of public enterprises and local authorities, and creating bottlenecks in their own activities. Other problems can be traced to a lack of technical capacity in the national and local institutions managing the urban transport sector. Engineering and economic know-how of urban public transport, essential for developing a good policy, is not well represented in the MOI, nor in city governments. An important related area, urban traffic management, is not even acknowledged as a distinct profession in Morocco.

Independent of the exact stategy selected for the treatment of the MTCs, or the detailed composition of the overall policy, the first priority on the road to recovery is an investment in the institutional system itself. Assuming that the requisite political consensus is reached, institutional development should be done by building up the technical capacity both of national and local government personnel, the latter in parallel with gradually decentralizing the resource generation and the decision making. At the national level, new forms of cooperation among ministries and other relevant institutions should be sought to ensure consistency of actions.

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Privatization of Urban Transit: A Different Perspective

Alan Black

Although urban mass transportation began in the private sector, the public sector had taken over most U.S. transit systems by 1980. The Reagan administration reversed this trend by making privatization of transit a major policy approach. This policy has been controversial; it has been opposed by many transit officials, some members of Congress, and especially labor unions. There are numerous opportunities for private enterprise to become involved in mass transit, and the process has taken place increasingly in recent years. Privatization gets many favorable reviews: it is claimed that private firms are more economic, efficient, productive, flexible, and innovative in providing transit service. The emphasis has been on cost savings because transit operating costs have risen greatly in recent decades. There is ample evidence that private firms often achieve lower costs. There has been little study of the reasons for the cost savings. The existence of unions may be the significant factor, rather than whether the enterprise is public or private. The limited data available show that nonunion private workers receive much less compensation than public workers. Unionized private workers fall in between. The welfare of transit workers should be a matter of public concern. One important issue is whether private firms are exploiting their employees. This topic deserves further study because transit workers should not shoulder an undue burden for reducing the subsidies for transit service.

Privatization of urban transit was one of the major changes in transportation policy initiated during the 1980s. Most reports of experiences with privatization have emphasized the cost savings achieved when public transit authorities contract with private companies to replace services they formerly operated themselves. There has been relatively little study of the reasons for the economies, but there is growing evidence that they arise because most private firms use nonunion labor and offer lower wages and benefits. Privatization is therefore examined from the perspective of the impact on transit workers.

BACKGROUND

Urban mass transportation in this country originated wholly in the private sector. All of the early means of transit of the 19th century—the omnibus, the horsecar, the cablecar, the electric streetcar, and the elevated railway—were built, owned, and operated by private companies. Entrepreneurs took the risks; some failed but many made large profits. At first, there was intense competition, but over time stronger companies bought out weaker ones, and monopolies emerged in many cities.

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Public involvement in urban transit began with the construction of subways, which required huge capital investments. The first subways in Boston and New York were built with public funds, and long-term leases were given to private companies to operate them. The first municipal government to operate mass transit service was San Francisco, which in 1912 formed the San Francisco Municipal Railway to build two tunnels and operate streetcar routes in the western part of the city (*1*). Soon after, the street railways in Seattle and Detroit became publicly operated. New York built an independent subway system that was publicly owned and operated from the start. Private transit companies were not popular at the time because they had been involved in many scandals exposed by crusading journalists.

The usual reaction of government to cases of private corruption was to regulate the private firms more strictly, rather than to take them over. By 1940, only 20 transit systems in the country (2 percent of the total) were publicly owned (*2*). New York City bought out two private companies that year and made the whole subway system public. A few other large cities did likewise: Cleveland created a public transit system in 1942, Chicago in 1946, and Boston the following year.

During the 1950s, transit ridership fell precipitously, and many private companies began to lose money. When they raised fares, patronage declined further, leading to another fare hike, and a vicious cycle ensued. Eventually many companies went out of business, and hundreds of smaller cities lost all transit service. In some larger cities, where transit was considered essential, private firms were taken over by government or given subsidies to keep them going, although often at a reduced scale.

The Urban Mass Transportation Act of 1964 introduced federal grants for capital investment in transit, and they could be used to buy out private companies. All remaining large private transit firms, plus many smaller ones, went into public ownership during the 1960s and 1970s. By 1983, there were 599 publicly owned systems, representing 58 percent of all systems in the country. They owned 93 percent of the vehicles, operated 95 percent of the vehicle-miles, and carried 95 percent of the passenger trips (*2*).

The Urban Mass Transportation Act included two protections for private enterprise. Section 3(e) restricted the use of federal funds "for the operation of mass transportation facilities or equipment in competition with, or supplementary to, the service provided by an existing mass transportation company." Section 8(e) required that federally aided transportation plans and programs "shall encourage to the maximum extent feasible the participation of private enterprise." There were some efforts to avoid negative impacts on private taxi companies, but otherwise little was made of these provisions.

In most metropolitan areas, all transit services were brought under one public transit authority. Most planners considered this desirable, as it permitted comprehensive planning and better coordination of services. Federal programs encouraged this: Federal aid had to go to public bodies (except for services for elderly and handicapped), and proposed changes had to fit into a metropolitan transportation plan.

However, the transit agencies were monopolies that could be indifferent to changing demand and hostile to competition. For example, the Washington Metropolitan Area Transit Authority refused to provide service to the new town of Reston, Virginia, claiming the route would not be cost-effective. In 1968, some Reston residents formed a commuter club and hired a private company to run express buses to downtown Washington (*3*).

The Reagan administration greatly revamped transportation policies. According to Smerk, "Mass transit is often viewed by the White House and the U.S. Department of Transportation as a particularly good example of wasteful allocation of resources by the public sector" (*1*,p.87). The administration repeatedly tried to terminate federal operating subsidies for transit. Congress resisted and the subsidies continued, but at lower levels. The budget of the Urban Mass Transportation Administration (UMTA) declined steadily during the 1980s.

The administration espoused a policy of privatizing urban transit, even though historically most private firms had left the business voluntarily. In 1984, UMTA issued a policy that "charged localities with the responsibility of demonstrating that they were *actively* encouraging private firms to participate in the provision of new and restructured local services. Unless UMTA was satisfied on this score, localities would not be able to obtain or retain matching funds for these services" (*4*,p.9). In 1986, UMTA published guidelines requiring applicants for transit aid to submit documentation of their privatization efforts, including analysis of whether existing public services could be provided by private operators.

This policy has been opposed by many transit officials, some members of Congress, and especially labor unions. Hence, in the words of Teal, privatization has "produced the most intense controversy of any federal transit policy initiative of the past twenty years" (*5*,p.10).

LABOR UNIONS

An account of the role of labor unions in the transit industry is appropriate. The industry has been highly organized since early in this century. The largest national union of transit workers, now called the Amalgamated Transit Union, was formed in 1892. A second major union, the Transport Workers Union, was created in 1934 and has jurisdiction in New York, Philadelphia, and a few other large cities. More than 95 percent of public transit systems in the country have unions (*6*).

In the last 25 years, the unions have obtained substantial increases in wages and benefits. Although many locals prefer arbitration as the means of resolving contract disputes, strikes do occur. They cause great disruption in large cities that are transit dependent (as happened in New York City in 1966 and 1980). Because of Section 13(c) of the Urban Mass Transportation Act (the labor protection clause), locals must sign off on applications for federal transit aid made by their employers. Allegedly this clause gives unions great power in bargaining with transit authorities, although this is a subject of debate. However, there is no doubt that the strength of the unions is a major reason why operating costs have risen sharply.

Work rules are important and may be elaborately specified in labor contracts. Transit workers usually receive premium payments for unattractive assignments. Because the demand for transit service is concentrated in two peak periods a day, it would be advantageous for management to put many operators on split shifts, with an unpaid break in the middle of the day. Workers find this schedule objectionable, so most contracts include premium payments based on the spread from first reporting to leaving for the day. Typical are the rules at the Massachusetts Bay Transportation Authority (MBTA): if the spread exceeds 10 hours, time-and-a-half is paid for the 11th and 12th hours, and double time for the 13th hour. A spread beyond 13 hours is prohibited.

Transit workers often have guaranteed minimum pay. In many cases, they are guaranteed at least 8 hours' pay for any day in which they must report for work. These guarantees originated as a way to dissuade management from using part-time workers. In the past decade, most public transit agencies have secured the right to hire part-time workers who do not receive the guarantees. However, this trend has not produced the anticipated cost savings for two reasons: (a) many contracts limit the number of part-timers to some small percentage of full-time workers, and (b) often management has made concessions in wages to get the right to hire part-timers (*7*).

Many transit workers routinely receive overtime pay, and some of them regard it as a prerequisite of seniority. The difficulty of scheduling transit service creates this situation. Often there are short pieces of work late in the day, and it is more economical to pay overtime than to put on another operator. This is one reason why unions are opposed to part-time workers.

Most public transit workers receive generous fringe benefits of the usual types: health insurance, pensions, sick leave, holidays, and vacations. The cost of fringe benefits can amount to 50 percent of the direct wage bill. Absenteeism has been a chronic problem in the industry, and sick pay is a major expense. Vacations start at a modest level, but workers with 20 years' experience may be entitled to 5 or 6 weeks off a year.

It is a matter of opinion whether union workers deserve these rewards. There has been some public reaction against them. In 1980, the Massachusetts legislature passed the *Management Rights Act*, which overrode key provisions of contracts between the MBTA and its unions. Among other things, the law prohibited cost-of-living adjustments in wages and authorized contracting with private firms and hiring part-time employees.

The justification for work rules is disputed. Schwieterman, a proponent of privatization, charged that "the most extreme examples of featherbedding, which have long disappeared from other sectors of the transportation industry, remain intact in the U.S. transit industry" (*8*,p.1). But Barnum, an expert on transit labor, stated, "There have been few reports of extensive 'featherbedding' in the transit industry, as is alleged to occur on the railroads. There is little opportunity for such practices in bus systems. . . . Little featherbedding has been alleged on the rapid rail lines either" (*6*).

The unions have strenuously fought privatization. Teal stated, "It is a rare transit agency that can engage in service contracting without a major struggle with its labor force" (*9*,p.34). Although Section 13(c) protects job rights of existing transit workers, it does not cover newly created jobs. If a private firm gets a contract from a public agency, it is free to hire nonunion workers. The unions may find themselves with a shrinking portion of the transit labor force if private companies get more and more of the business.

OPPORTUNITIES FOR PRIVATE ENTERPRISE

There are numerous opportunities for private firms in urban transit. Actually they never totally left transit; many companies have continued to function in the field in various capacities, but they have remained in the background and have gotten little notice. The transit authorities have created the impression that all mass transit is public, which is not correct.

In some places, private firms supply all transit service under contract to public bodies. There are four private professional management firms that specialize in this business; they run 20 to 25 percent of the publicly owned systems. This includes some sizable operations; private companies provide all bus service in Honolulu, Phoenix, and Westchester County, New York.

More commonly, transit authorities contract with private companies for only part of their service or for certain specific functions. Smerk (*1*) described the following opportunities for the private sector:

1. Use of private firms to perform support activities, such as building and vehicle maintenance, vehicle cleaning, printing of schedules, advertising, and accounting.
2. Provision of demand-responsive transit, such as dial-a-ride or shared taxi. According to a national survey conducted in 1985, one-third of all demand-responsive services are contracted to private firms (*10*). Often these services are supplied by taxi companies, which have the most experience in providing door-to-door service. A majority of special services for the elderly and handicapped are run by private firms. Some transit agencies have replaced fixed routes that had low ridership with demand-responsive service provided by private carriers. Examples are routes in low-density areas and evening and weekend service.
3. Long commuter runs from residential areas to the central business district. Several private railroads continue to operate commuter trains under contract to public agencies, but the most common examples are express buses that run only in the peak period and peak direction. Private firms offer such services in Boston, New York, Chicago, Houston, Los Angeles, and several other cities. Often these routes tap high- or upper-middle-income areas and have high fares. Some of these services are subsidized, but some are not; this form of transit can be profitable (*11*). Some transit authorities welcome it because it skims off part of peak-period demand. The marginal cost of peak-period service is high because extra equipment and personnel are needed for a few hours a day and remain idle otherwise.
4. Joint development at transit stations. This idea is not new—it was done in some early subways—but it has received attention in recent years as a way of increasing income for transit agencies. An example from Atlanta is ReSurgens Plaza, a 27-story office building erected over the Lenox rail station. Passengers leaving trains walk a few feet to elevators that go to any floor of the building. The developer leased air rights from 40 ft above ground upward, plus toeholds for the columns that support the building.
5. Contracting out ordinary fixed routes to private operators. This is the notion that has gotten the most publicity about privatization. The idea is to solicit bids to operate individual routes. Supposedly private firms competing with each other will become more efficient to submit low bids, and the public will benefit from the improved efficiency. This approach has been implemented in many places. Perhaps the largest test is taking place in Denver; in 1988 the state legislature mandated that the Denver Regional Transportation District privatize at least 20 percent of its bus service.

Another scenario occurs in unique situations: A private company provides a specialized transit service as an adjunct of a larger enterprise. In Fort Worth, the Tandy Corporation runs free streetcars between a large parking lot and Tandy Center, a downtown shopping mall. For $7 million, the developer of Harbour Island in Tampa Bay built an automated people-mover that connects with downtown. After 15 years, it will be transferred to the transit authority for $1. Privately financed people-movers are also under construction at the Las Colinas new town near Dallas and in Las Vegas. In these cases, the transit system serves a real estate development from which the private firms benefit. Generally, the transit service itself is not expected to make money.

ARGUMENTS FOR PRIVATIZATION

Proponents of privatization do not claim private enterprise is always superior to public operation. In the past, they note, many private transit companies suffered from bad or corrupt management, and many were monopolies. The real issue is monopoly versus competition. As Teal noted, "Monopoly organization, particularly when combined with dedicated transit subsidies, insulates transit managers from economic or political pressures to stress cost-effectiveness when making service delivery decisions" (*9*,p.34).

When transit authorities have dedicated sources of funding, as many do, they may have little incentive to cut costs (*12*). A transit district that levies a sales tax receives the same amount of money whether or not it is efficient. It is not feasible to pass on cost savings by lowering the tax rate. The tax revenues are earmarked for the transit district and cannot be used for other public purposes. (However, if the agency has a tight budget, it may be highly interested in cost savings.)

Specific claims for privatization of transit are as follows:

1. It lowers the costs of providing transit service. Although a private firm under contract makes a profit, it costs are so much lower that the transit authority spends less money, and the public pays less in taxes. This is the most important argument because the operating costs of public transit systems have soared in recent years, causing many financial crises (*13*).

2. Private firms are more efficient than public agencies. According to former UMTA Administrator Ralph Stanley, "We've taken a look at the economics of running a bus system, and shown beyond a doubt that it's more efficient to be run privately" (*14*,p.12). It is argued that private firms have better management because compensation is more closely related to performance and not limited by rigid pay scales.

3. Private firms have higher productivity than public agencies. There are several measures of productivity in transit, such as vehicle-miles supplied per worker or passengers carried per worker. The recent record of transit has not been good. By most measures, productivity has been stagnant or has actually declined. Even when there have been increases, they have been less than increases in costs (*13*).

4. Private firms are more flexible than public agencies. They can adapt to changing situations better and more quickly. Private companies are less hampered by bureaucratic procedures and more immune to political influence. A private boss can fire a worker who is performing badly, but this may be difficult in a civil service system. A private manager tries to cut out parts of the business that lose money; public officials are reluctant to cut services because of the political risk.

5. Private firms are more innovative, more responsive to changes in demand, more willing to take risks. For example, in New York City, a multitude of private services has emerged spontaneously to fill gaps left by the Transit Authority (*15*). Private entrepreneurs are motivated by the possibility of large profits; public employees do not have this incentive and are more concerned with security. They can suffer harsh penalties for being wrong, so it is wisest to follow the rules and maintain the status quo.

These arguments are based on the virtues of competition, and some people have questioned the extent to which privatization produces competition. Because the public sector has long dominated urban transit, there are relatively few private firms equipped to supply bus service to the general public. Sometimes there have been no responses to a call for bids, or only a single response.

Hence, competitive bidding may not occur; many contracts are negotiated. Although the majority of contracts are for 1 year, often contracts are renewed without seeking new bids. It is alleged that some firms "low-ball" their first bids, meaning they offer an initial price below what they would have to charge in the long run to be profitable (*4*). In this way, they establish market position and can raise prices later.

However, it is argued that free entry to the market poses the threat of potential competition, which forces a monopoly to act in a competitive manner. Morlok stated that "there need not be overt competition between prospective service producers to provide the pressure necessary to keep costs low. All that is necessary is the possibility that another firm could enter the market if the present producer became inefficient" (*16*,p.56).

COMPARISON OF PUBLIC AND PRIVATE COSTS

There have been many studies comparing the costs of transit services operated by public agencies and private companies. It is difficult to make fair comparisons because so many factors vary. As Teal noted, "Only in the case where a private operator replaces or is a substitute for public agency operation of an entire public transportation service can any precision be attached to cost savings" (*9*,p.32). This case is rare; many comparisons involve different cities or different routes. Although the costs of private firms are known from contracts, it is much harder to determine public agency costs for individual routes that are only part of a system. Often, these are estimated from cost allocation models that involve considerable uncertainty.

There are systematic biases that can mask the comparison of public versus private. Costs tend to be lower in small cities than in large metropolitan areas, partly because wage rates are lower. Generally unit costs are lower for small systems than large ones; there do not appear to be economies of scale in bus operation (*16*). The private operations are small to medium-sized; all of the large systems in the country are public.

Teal has probably collected the most data on comparative costs. In one paper, he concluded that "private sector contracting can produce cost savings of 15 to 60 percent" (*9*,p.28). For all-day, fixed-route bus systems, he found that private contractors achieved savings ranging from 22 to 54 percent. For commuter bus services, private contractors had cost advantages ranging from 25 to 58 percent. For demand-responsive service for the general public, the cost savings were around 50 percent, with one exception.

Later, Teal conducted a national mail survey of public transit sponsors which yielded more than 800 responses (*10*). About 35 percent of the agencies contracted for at least part of their service. The survey revealed small differences between average public and private costs; for small systems (up to 50 vehicles), private costs were less than 10 percent lower. For medium-sized systems, cost advantages of private firms ranged from 9 to 23 percent.

Morlok reviewed several studies and concluded that "those cases in which competitive bidding was used resulted in private firms being able to produce the transit service at a lower cost—typically about 50 percent less—than the public regional authority could" (*16*,p.56). He noted that some private firms with noncompetitive contracts were more expensive than public agencies.

In New York City, six private companies operate local bus service, primarily in Queens. Researchers at Columbia University studied these firms and compared them with the TA. They found that "The private companies as a group are consistently more efficient and more cost-effective than the NYCTA. In 1984, operating cost per vehicle-mile for the privates was 76 percent of the TA level, while the privates obtained 74 percent more vehicle-miles per employee hour" (*17*,p.562).

Rosenbloom has done extensive research on transportation services for the elderly and handicapped, an area in which private firms have been active for many years. She found that cost per trip spans a wide range both for private and public providers and there is considerable overlap (*18*).

WHY PRIVATE COSTS ARE LOWER

Thus there is considerable evidence that private firms can supply transit services at lower cost than public agencies. Whether this outcome is desirable, as advocates of privatization see it, depends on why private costs are lower. There has been little research designed to probe the reasons why private firms have lower costs and to measure their impacts.

Critics of privatization have suggested that the cost comparisons are specious. Sclar et al. (*4*) argued that there is a bias because the fully allocated costs of a public system are compared with the incremental costs of a private firm for operating one or a few routes. The public costs include overhead, administration, planning, etc., whereas the private costs do not.

Another argument is that private firms lower the quality of service. Teal noted that, "the fact that negative experiences do occur gives credence to the belief of many transit managers that service quality can be a problem in contracting" (*9*,p.35). Hence the public agency should carefully specify quality standards in contracts and monitor performance of private firms. This extra effort means that the private firms' costs are not the full costs of contracting.

These points are valid, but they cannot explain all of the large cost differences reported. Undoubtedly, some private companies do manage better than public agencies. Here are some examples: (a) private firms use smaller vehicles (minibuses and vans) that are sufficient for low demand, whereas a transit authority may have only full-sized buses available; (b) the privates spend less on spare parts (federal aid makes it attractive for public agencies to stock parts); (c) the privates schedule their workforce more efficiently, paying less overtime and keeping fewer operators on standby; and (d) private firms use part-time workers much more than public agencies.

It appears that many private firms have lower overhead. In part, this is because they tend to be small enterprises, and evidence suggests there are diseconomies of scale in bus systems. It is often alleged that public agencies are swollen bureaucracies with redundant staff, and it may be true. Whatever the reason, private companies seem to have fewer employees who are not engaged in the actual delivery of transportation services.

Political interference raises costs in some public transit systems. In particular, proposals to reduce service often generate neighborhood protests that reach the ears of elected officials. Transit authority boards of directors are frequently political appointees who are sensitive to such reactions. In addition, there are patronage jobs at some transit agencies.

However, the major reason why private costs are lower is that the workers receive less income. Transit service is labor-intensive; nationally, labor costs (including fringe benefits) made up 72 percent of operating costs in 1988 (*2*). Despite publicity about energy costs, they account for less than 10 percent of operating costs. The main way to reduce total costs is to cut labor costs. As Rosenbloom noted, "Some of the current cost advantages enjoyed by private providers are simply a result of lower labor costs and not more efficient management or production" (*18*,p.44).

The private companies achieve lower labor costs mainly because they use nonunion labor, pay lower wages, and offer fewer benefits. For example, bus drivers for the Kansas City Area Transportation Authority, who have a union, get a top scale of $13.07 per hour. In nearby Johnson County, Kansas, where a private firm supplies the service and there is no union, the maximum wage is $7.00 an hour. According to a Florida union official, private firms "can hire people easily for half the price that they pay our people" (*14*,p.68).

The presence or absence of unions may be the significant factor, rather than whether the enterprise is public or private. What is needed to clarify the issue is a 2 × 2 table comparing union versus nonunion as well as public versus private. Because almost all public transit agencies have unions, the cell for public, nonunion systems would be virtually empty.

That workers at some private transit companies do have unions is especially true of older companies that escaped the transition to public ownership. The spread of transit unions occurred in the era when the transit industry was mostly in the private sector. But today, private company locals are small and weak compared to those at large public transit authorities. A union that can severely disrupt the daily travel pattern of a major metropolis is to be feared; one that controls a minor bus service has little clout.

Although there has been no national comparison of transit labor costs, there is one relevant study. Peterson et al. (*19*) collected data on transit worker compensation in eight metropolitan areas (Boston, Chicago, Detroit, Houston, Los Angeles, New York, Seattle, and Washington). This sample was not systematic, but these areas contained 35 percent of public bus operators in the country and 95 percent of rail operators. The study showed that on the average, the compensation level (wages plus fringe benefits) for unionized bus drivers at private companies was 21 percent less than for public agency bus drivers. Compensation for nonunionized bus drivers at private companies was 45 percent lower than for drivers at public systems.

In the Boston area, 16 private companies as well as the MBTA offer bus service. In 1988, the maximum hourly wage for an MBTA bus driver was $14.63. Nine private companies with unions paid drivers an average top wage of $10.00 per hour. The average for seven private companies without unions was $8.79.

Lower labor costs stem from differences in fringe benefits and work rules as well as hourly wage rates. Herzenberg (*20*) did a detailed cost analysis of 12 MBTA bus routes that were considered good candidates for privatization. She concluded that the MBTA could save about $12,000 a day by contracting with private firms to provide drivers and maintenance (this is equivalent to at least $3 million a year). The total was broken down as follows: $2,000 to $4,000 from the difference in basic wage rates, $3,700 from fringe benefits, $1,400 from work rules, and $3,000 to $4,000 from maintenance labor costs.

The New York case mentioned earlier is interesting because all of the private companies were unionized and their wage rates were close to what the transit authority paid. Even so, the private firms had much lower labor costs, largely because of work rules; they did not pay penalties for split shifts, resulting in a 30 percent saving in operator costs (*17*).

THE IMPACT ON TRANSIT WORKERS

Most writers on privatization realize that cost reductions result from lower wages and using nonunion workers, but many see no objection to this. Some argue that the private company workers are satisfied because they might not have jobs otherwise, and there are compensating advantages. Morlok (*16*) suggested several reasons why employees of small private firms might be content with their situation:

1. "Workers seem willing to trade off the increased recognition of their work and importance of their position in a smaller firm for somewhat lower wages."
2. "There is probably less chance of a labor-management agreement in small firms specifying regulations that lead to some workers being paid for time during which no work is performed. In a small firm, there tends to be a lack of anonymity among workers, and workers in jobs that require a full effort would be aware and resentful of other workers with an easy job or nothing to do."
3. "Firms that are successful in keeping wages low seem to choose their workers carefully. Often they try to hire persons who want to work part time only and who are not the main breadwinners for their families."

With regard to the last point, a study of part-time operators at public transit agencies found that the majority would prefer full-time work (*7*). It was expected that most part-timers would be college students, retirees, or mothers of young children who wanted permanent part-time work. Instead, most were people unable to find any full-time jobs. The supply of part-time workers responded to the economic cycle; it went up when the unemployment rate was high, and down when it was low. Possibly, private firms do better at recruiting people who truly want part-time work, but it is not proven.

Others believe that unionized transit workers are overpaid and get extravagant benefits. Transit operators are semiskilled blue-collar workers; there are no education requirements and their training is brief. However, they bear a sizable responsibility for public safety and their work is not easy. It is difficult to determine fair wages by comparing with other occupations. Peterson et al. (*19*) found that in the eight metropolitan areas they studied, on the average public bus drivers received compensation 5 percent greater than public elementary school teachers, but 20 percent less than police officers.

Some investigators have pointed disparagingly to the high absenteeism record of public transit workers. Fielding (*21*) claimed that private transit companies have less absenteeism, and this is a major reason for their lower costs. Most transit labor contracts impose a waiting period before workers receive any sick pay, and then they must submit a doctor's confirmation. It is common for transit workers to take unpaid days off; this procedure is positively correlated with the availability of overtime (*22*).

Absenteeism stems at least in part from occupational health hazards. In a review of numerous studies, Long and Perry found that, "transit operators appear to be more susceptible to health disorders such as hypertension, gastrointestinal disorders, nervous disorders, and back problems than a variety of occupational groups" (*22*,p.257). Major factors contributing to stress are exposure to violence, dealing with difficult passengers, and pressure to keep to schedule in congested traffic.

Some regard privatization as a way to break the power of transit unions and force concessions. Schwieterman and Schofer recommended that "government should use the presence of the private sector as a basis for strengthening its bargaining position with organized labor and contract carriers. Efforts to modernize work rules, eliminate featherbedding, allow split-shifts and other cost containment measures should be intensified" (*23*,p.36).

Transit privatization has also occurred in Britain, which deregulated all local bus services outside Greater London in 1986. According to Gomez-Ibanez and Meyer, "The clearest losers from deregulation so far have been unionized local bus workers since they have suffered reductions in both their wage and premium rates and in the levels of total employment" (*24*,p.93).

Some believe the situation is temporary; eventually employees of private transit firms will form unions and their wages will go up. This process is uncertain. Teal commented, "the prospects for organizing the employees of the private contractor are not particularly bright, as a policy of competitive procurement of services will favor private companies with low-to-moderate wages" (*5*,p.11). That is, companies that pay higher wages won't get much business.

The transit unions have indeed secured substantial wage increases and other benefits for their members in the past 25 years. It is debatable whether these benefits should be curtailed. It may seem appealing to achieve efficiency by eliminating work rules that invoke penalties for split shifts. But split shifts are unpleasant; there may be a span of 13 hours between first reporting to work and finally leaving for the day. It is reasonable that some financial compensation be given for working under undesirable conditions.

The welfare of transit workers should be a matter of public concern. For one thing, there are increasing proportions of blacks, Hispanics, and women in the transit labor force. The issues about privatization involve ethics and equity, not just efficiency and economy. One important issue is whether private firms are taking advantage of their employees.

This topic deserves more research. There should be a comprehensive comparison of public and private transit operators with regard to basic wage rates, fringe benefits, work rules (including premium payments), and use of part-time workers. Also needed is investigation of the quality of work life for employees of private transit firms. Evidence on this could come from surveys and interviews, but also from data on attrition, absenteeism, on-the-job injuries, grievances, and attempts to organize unions.

CONCLUSIONS

There are advantages in encouraging private firms to enter the transit business. In some cases, they do operate services more efficiently, probably because they are less affected by bureaucratic and political constraints. There is no compelling reason why public transit authorities should be monopolies, although they should be given the opportunity to coordinate private services with their own operations. The existence of private competitors should stimulate transit authorities to improve their marketing and management. Some of the cost-saving measures used by private companies could be adopted by public agencies.

The reason for the cost savings reported for private firms needs more thorough study. The savings may have been achieved largely at the expense of transit workers. Herzenberg framed the issue well: "Policy makers deciding whether or not to subcontract private operators to provide drivers and maintenance services should understand that, in doing so, they are implying that the wages and working conditions for MBTA drivers are less reasonable than those for private company drivers" (*20*,p.130).

The role of labor unions is an important aspect of privatization that has been neglected. A policy on privatization implies a position on unions. Those who favor collective bargaining should be skeptical about privatization. Those who think unions have achieved too much power should find privatization agreeable. In either case, the existence of unions is a fact of life that transit policy makers cannot ignore.

More important is the question whether privatization leads to exploitation of transit workers. Transit subsidies are often justified on the grounds that they redistribute income to the disadvantaged. Privatization shifts some of the burden for this from the general taxpaying public to those individuals who are employed in the transit industry (and who themselves may be poor, female, or minority).

There is reason to fear that private firms exploit their workers by paying them less than the public authorities and offering less desirable working conditions. This topic deserves further research. If it is true, and privatization is to continue, then legislators should consider arranging some protection for the employees of private transit companies.

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Multivariate Time-Series Model of Transit Ridership Based on Historical, Aggregate Data: The Past, Present and Future of Honolulu

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Historical data on a small number of economic, demographic, and transportation variables from 1958 to 1986 were analyzed by multiple regression techniques to develop two models for forecasting transit ridership in Honolulu. A model predicting revenue trips and another for linked trips were consistent in their determination that the same five variables could account for 97 to 98 percent of the variance in bus ridership over this 29-year period. The four major variables were per capita income, employment, fares, and size of bus fleet, with a dummy variable included for strikes. The income elasticity for transit demand was found to be negative, indicating that mass transit is an inferior good. The model forecasts a continuing decline in bus ridership for Honolulu, mainly caused by this effect. The forecasting models for rapid transit ridership for Honolulu are examined, and alternative approaches to assessing demand elasticities are discussed. The advantages of using aggregate historical data and regression analyses for developing inexpensive forecasting models from time series data are emphasized.

Two multivariate models to forecast transit ridership for Honolulu using aggregate variables are presented and discussed with respect to different modeling approaches and their applications. The two models use the statistical technique of multiple regression that is widely used in economic forecasting and model construction in the other social sciences (*1,2*). This approach is most commonly used in transportation to study trends in time series data (*3–7*) and it is particularly useful for analyzing secondary sources of historical data (*8,9*). As such, it is well suited for long-range planning and it can be a valuable tool for transportation planners who have only limited resources available to them.

ELASTICITY OF TRANSIT DEMAND

The demand for transit (transit ridership), like that for any product, is related to two variables: price and income. The price relationship is best known. The demand for a product is inversely related to its price; or simply, the lower the price the higher the quantity demanded. Although the direction of this relationship is universal, the degree to which demand for a product changes with price—i.e., its price elasticity—varies considerably. If a given percentage change in price results in a proportionate or higher change in demand, the price elasticity is said to be elastic. If a percentage change in price results in a proportionally smaller change in demand (less than 1:1 ratio), the elasticity is said to be inelastic.

The concept of elasticity has important implications for transit operators. If the price elasticity of transit is elastic, then lowering fares (price) would increase ridership and revenues, whereas increasing fares would decrease both measures. If, however, demand is inelastic, lowering fares would increase ridership but decrease revenues, because the percentage increase in ridership would not be large enough to compensate for the drop in fares. Raising fares, on the other hand, would actually increase revenues despite decreasing ridership, because the ridership loss would be proportionally less than the fare increase.

The negative relationship between fare and ridership has been confirmed by many studies and the demand for mass transit is clearly inelastic (*5,6,10–13*). Fare elasticities for mass transit rarely are less than −0.70, with elasticities in the range of −0.20 to −0.60 being most common (*10–13,14*).

The second economic variable that must be considered in transit planning is income. Although income is recognized as an important variable determining choice of travel mode (*11*), only a few studies (e.g., *6,15*) have analyzed income elasticity with respect to transit ridership.

The income elasticity of most products is positive in that the demand for them increases with income. Some products, however, have a negative income elasticity in that demand for them decreases as income rises. Such products are called "inferior goods."

The income elasticity of a product is important for long-range planning purposes, because, if a product has a negative income elasticity and income is expected to rise, then long-run demand for that product can be expected to decline. This should be a matter of some concern to transit planners because transit may be an inferior good.

National demographic data on transit patronage suggest that fixed-route buses and trains are inferior goods (*16,17*),

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but few studies have calculated the income elasticity of transit ridership. Gaudry (*6*) found a negative income elasticity for transit in Montreal, but the effect of income in his ridership model was not significant. Gordon and Willson's (*8*) international analysis of rail transit, as well as other studies, provide indirect evidence that transit demand has a negative income elasticity (*12,15*).

DEMAND ELASTICITY AND TRANSIT SERVICE

The service characteristics of transit systems provide the supply functions that contribute to transit patronage (i.e., ridership). The service characteristic that has been found to be most influential in predicting ridership is the quantity of service (*7,11,13*). Carstens and Csanyi's (*18*) analysis of bus ridership in 13 Iowa cities indicated that revenue ridership was highly elastic in terms of miles of service. The results of other studies are not as optimistic. Although Rose (*7*) reports that the service elasticity for ridership on the Chicago rail system is both positive and elastic (elasticity = 1.84), his demand measure was not limited to revenue ridership. In other U.S. cities that have been examined (*13,19*), the relationship between transit ridership and miles of service, though positive, is inelastic (0.21 to 0.87). Although Kemp's survey of 35 demonstration projects reveals that transit ridership is more sensitive to changes in service than it is to fares, it appears from his survey that the increased revenues resulting from service increases are not enough to offset their cost.

Other factors also contribute to transit demand, and service measures of transit supply appear to play only a minor role in mode choice when demographic variables, such as income and automobile ownership, are taken into account (*6,8,12,15,18*). Demographic factors may also influence the effects of other variables. Fare elasticity, for instance, appears to vary inversely with city population size (*12,18*).

AVAILABLE AND SELECTED MEASURES

Various historical data were available from the start of Honolulu's all-bus transit system in 1957 (trolley service ended in 1956) to the present, including revenue passengers and total annual ridership (*20–24*). The only service measure available for this span of time was size of bus fleet (number of buses). Although it is admittedly a crude measure of service, it is the sole service factor that is used in policy proposals about future bus operations.

Four of the historical variables that were available are also forecast by the Department of Business and Economic Development (DBED) through the year 2010 (*25*). These variables are per capita income, population, number of visitors (tourists), and civilian employment (actual number of jobs held). Per capita income was naturally included in the model for determining income elasticity. Because the other three variables were all highly correlated, it was decided to start the model with only one of them. Employment was chosen because it was closely related to transit demand both in theory and practice. Other relevant variables for which data were available included number of registered passenger vehicles, gasoline prices, and bus fare. Bus fare was another natural choice for the model variable but the fare structure for the bus system posed some of the same problems encountered by Bates (*3*). Nevertheless, the average fare calculated from official estimates of passengers in different fare categories was comparable to that reported in recent annual reports of the Honolulu bus system. A dummy variable was entered into the model to account for two strikes of over 1 month's duration.

BUS RIDERSHIP MODELS

Two models were constructed using the statistical technique of least squares multiple regression. The first of these was developed to predict annual passenger revenue-trips (R-TRIPS) and the second to predict annual linked trips (L-TRIPS), or initial boardings.

Revenue Trips Model

The revenue-trips model consisted of five variables: (a) the natural logarithm (ln) of the number of civilian jobs (JOBS), (b) ln of per capita income in 1982 dollars (INCOME), (c) ln of fare in 1982 dollars, (d) ln of the number of buses in the bus fleet (BUSES), and (e) a dummy variable for strikes (STRIKES).

The full model for annual revenue trips is expressed as follows, with all values given in \$ millions:

$$\begin{aligned}\text{R-TRIPS} = &-118.9 + 52.2(\text{JOBS}) - 60.9(\text{INCOME}) \\ &- 27.8(\text{FARE}) + 7.9(\text{BUSES}) \\ &- 4.4(\text{STRIKES}) \qquad (1)\end{aligned}$$

On the basis of 29 observations, the model has an adjusted R^2 value of 0.97. The t-statistic values for the respective variables were 2.26, 4.26, 5.02, 5.37, 3.19, and 2.12. The first three variables are significant at the $p < 0.001$ level. The t-value for BUSES is significant at $p < 0.005$, whereas STRIKES has a probability $p = 0.05$. The goodness-of-fit between the model's estimates and the actual data is shown in Figure 1 (1967 and 1971 were strike years). The inclusion of other variables, such as tourists, registered passenger vehicles, and gasoline prices, did not significantly improve the model. As indicated by the formula, per capita income, fares, and strikes all have inverse relationships with revenue ridership, as would be expected. Numbers of jobs and buses, on the other hand, are positively related to revenue passengers.

A better understanding of the effects of these variables can be gleaned by looking at their elasticities, which yield direct estimates of their effects on ridership in standardized form. According to the model for revenue trips, the employment elasticity is 1.04, which means that each 10 percent increase in employment should result in a 10.4 percent increase in ridership. Increases in per capita income, on the other hand, have a negative effect on ridership. Given the model's estimated income elasticity of −0.98, a 10 percent increase in income should yield a 9.8 percent decrease in ridership.

Because the fare elasticity was −0.56, each 10 percent decrease in fare is expected to yield a 5.6 percent increase in

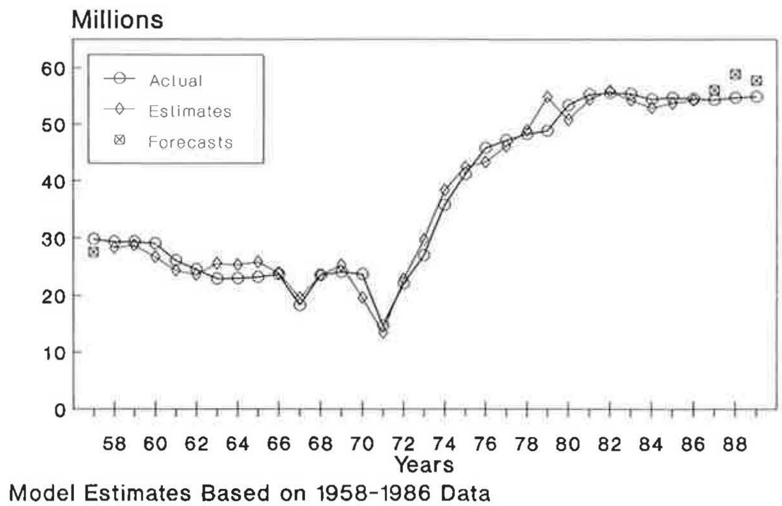

FIGURE 1 Actual and estimated annual revenue trips with forecasts for 1957 and 1987 to 1989.

ridership. Because Honolulu's bus system has had only a few small fare increases over the past 33 years, fares have continually declined in real dollars, helping to maintain ridership. But, because the fare elasticity is inelastic, the decline in fares produced decreased revenues.

The service elasticity, based on the number of buses, is 0.25. Hence, a 10 percent increase in number of buses can be expected to increase ridership only 2.5 percent. Of course, number of buses is only a crude measure of service, as stated earlier. Vehicle-miles of service would provide a more sensitive measure of service and, given past research, would likely produce a higher service elasticity than that found here (*7,19,26*). Nevertheless, for the years in which mileage data are available (1970 to 1989), the correlation between miles of service and number of buses is quite high, $r = 0.93$.

Linked Trips Model

Honolulu, like other cities, offers free bus passes to the elderly and handicapped, and free riders constitute just over 20 percent of all initial boardings. A second model was developed, therefore, to predict the total number of annual linked trips (revenue passengers plus free riders). Linked trips were derived from total annual trips by applying the correction factor for transfers used in the forecasting methodology for the Honolulu Rapid Transit Development Project (*27*), which was based on a 1986 on-board survey of bus riders.

The same five factors were found to predict linked trips as accurately as they did revenue trips. Adding other variables to the model, such as tourists, registered passenger vehicles, gasoline prices, and the percentage of free riders, did not improve it.

The model for annual linked trips (L-TRIPS) is as follows:

$$\text{L-TRIPS} = -118.3 + 38.2\ (\text{JOBS}) - 44.1\ (\text{INCOME}) - 36.0\ (\text{FARE}) + 10.6\ (\text{BUSES}) - 4.1\ (\text{STRIKES}) \quad (2)$$

Again, the model is based on 29 observations, with all coefficients given in $ millions. The respective t values are 2.30, 3.17, 3.71, 7.09, 4.38, and 2.02. The adjusted R^2 value for the model is 0.98. As before, the effects of INCOME and FARE are all significant at the $p < 0.001$ level; the effect of STRIKES is only marginally significant at $p < 0.06$. In the present model, however, the t value for BUSES is significant at the $p < 0.001$ level, whereas JOBS has a probability of $p < 0.005$. Although the directions of the effects are the same in the second model as they are in the first, the coefficients derived from the two models differ, as do the elasticities.

The employment elasticity in the linked trips model is only 0.64, compared to 1.04 in the revenue trips model, indicating that employment does not have as strong an effect on total linked trips. Likewise, per capita income, with an elasticity of -0.59, has less of a negative effect on linked trips than it does on revenue trips. These differences are consistent with the fact that a substantial portion of the added trips in the linked trips model are attributable to elderly passengers using free bus passes.

The fare elasticity (-0.61) and service elasticity (0.28) for the linked trips model changed relatively little from those found for revenue trips. All of the elasticities calculated are long run and relatively inelastic, indicating that increases in bus ridership cannot be expected in the foreseeable future.

Although there are differences in the elasticities of the two models, they do not lead to sharply divergent predictions. In fact, the forecasts from each model tend to parallel each other (see Figure 2). Furthermore, the signs of the coefficients of both models are consistent with what would be expected from the theory of consumer behavior and the literature on travel demand elasticities.

BUS RIDERSHIP FORECASTS

The two models were tested against actual ridership in 1957 and years 1987 through 1989. These tests are shown for the first model in Figure 1, where they are labeled forecasts. The

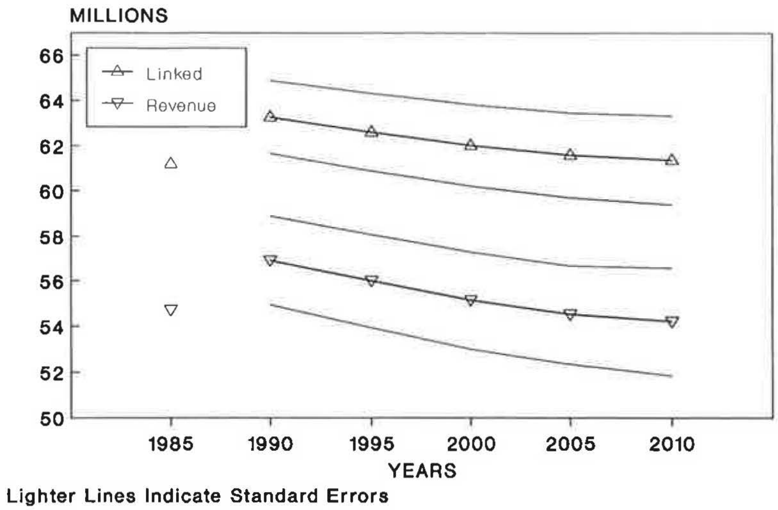

FIGURE 2 Forecasts of annual revenue trips and linked trips with current fares and buses.

goodness-of-fit for the models was further tested by calculating the mean absolute percentage error (MAPE) between model estimates and actual ridership for all years in the series (*2*). The MAPE was 5 percent in each case, confirming the high level of accuracy of the models. Both models, however, tend to overestimate current ridership, which has declined in the last few years. This recent downturn in ridership marks a significant trend ($z = 3.44$, $p < 0.001$), according to the change-point test (*28*), that is not predicted by the model.

Even so, the models do predict declining future ridership on Honolulu's bus system. Using DBED projections of per capita income and employment, the models forecast a reduction both in revenue trips and linked trips, holding fares and size of bus fleet constant.

The forecasted decreases in ridership are partially caused by the high negative income elasticity. Because the service elasticity is relatively inelastic, it would appear that significant increases in ridership can only be gained through substantial increases in bus fleet size. However, this result assumes that the bus fleet has been used in a way that maximizes service per bus and that number of buses is an adequate measure of service. If buses have been used inefficiently in the past or number of buses, per se, is a poor measure of service, the prediction may not be as dire. Because there is some evidence that recent decreases in ridership may be associated with less efficient use of the bus fleet (e.g., reassigning buses from urban trunk lines to express service for suburban commuters), improving service could offset declining ridership to some degree.

Decreases in real fare can be expected to continue to increase ridership, but at the expense of declining revenues. This process, unfortunately, increases the gap between revenues and costs. Although increases in employment have a positive effect on ridership, these expected gains tend to be counterbalanced by the income effect.

RAPID TRANSIT MODELS

The ridership forecasts for the proposed rapid transit system for Honolulu are derived from a model described by Brand and Benham (*29*), sometimes referred to as an incremental model (*27*). The Brand and Benham model has been empirically verified in a Maryland study, in which it proved quite useful for directly comparing the outcomes of different transit alternatives. However, there are some problems with the application of the model to Honolulu. Brand and Benham (*29*) cautioned that long-run elasticities should be used in any application of the model and that the elasticities used should be appropriate for the study area.

Unfortunately, no long-run elasticities derived specifically for Honolulu are used in making Honolulu's ridership projections (*27*). Although the incremental model used for these projections uses some of the same actual and projected demographic data that were tested in the models (fare, employment, population, and visitors), the long-run elasticities of these variables for transit in Honolulu have not been taken into account by project planners (*27*). Instead, the model arbitrarily assigns an elasticity of unity to population and employment changes to estimate their combined effects on transit ridership. Summed to form a single variable, the percentage change in population plus employment between the base (1985) and target (2005) years is used as a growth factor for forecasting transit ridership, aside from the affects of service variables. As such, the model essentially assumes that transit ridership will grow in the future, provided that population and employment increase.

Although it is likely that improvements in transit service will increase ridership, findings do not support the assumption of growth that is embedded in the model now being used (*27*). The models indicate that transit ridership does not simply grow with increases either in population or employment. In both models, the income elasticity was opposite in sign and almost equal in magnitude to the elasticity for employment. That, as explained earlier, is mainly why the models forecast declining bus ridership as employment and income increase in the future.

The analyses also challenge the propriety of combining employment and population data into a single variable. Because these two variables are highly intercorrelated, they cannot simply be added together, or summed. Doing so falsely magnifies their effects. Any linear combination of these factors that does not remove their common variance is statistically invalid. If their shared variance is removed, the added predictive value of population data, once employment values are known, is trivial.

Of course, the two models presented cannot be directly applied to forecasting ridership for the proposed rapid transit system. However, they do point to some deficiencies in the present model. The general trends for transit found in both models may be better estimates of future transit ridership. Related analyses, in which Gordon and Willson's (*8*) light-rail model was applied to Honolulu, also support this view (*30*). Thus, the potential improvements in transit service afforded by a rapid transit system may operate within the context of decreasing transit ridership and they may have to be sufficient to overcome this downward trend.

PROBLEMS IN ELASTICITY ESTIMATION

Studies attempting to measure the elasticity of transit demand have used a variety of research approaches and analytical techniques. For example, many studies of fare elasticity have used data from quasi-experimental demonstration projects in which fare is directly manipulated as an independent variable, or from "natural experiments" in which the effects of fare changes on transit ridership are observed (*4,12,31*). Another common research method is the cross-sectional analysis of travel behavior in some specified area at a given point in time using direct observation or survey methods (*11,12*). The third major approach in transportation research is the multivariate time series study, which, like cross-sectional research, attempts to determine the influence of a number of independent variables on travel behavior (*4–8*).

There are advantages and disadvantages to each type of research, including costs in terms of time and effort involved in data collection and analysis, data accuracy, and the reliability and generalizability of the results.

Some of the problems associated with different kinds of studies of transit demand are worth mentioning. The natural experiment, for example, cannot clearly differentiate between the effects of the independent variable and possible effects of extraneous variables, which may include seasonal variations, secular trends, and variations in supply and service adjustments that may occur during the same period of time (*11*). True quasi-experimental designs are able to overcome this problem of identification by measuring all relevant variables to see if a change in some extraneous variable is likely to account for, or contribute to, the observed change in the dependent variable.

A second type of problem is more common, even when a valid quasi-experimental design is used. Often data are collected only for two points in time that are separated by a relatively brief interval—typically a few months at best (*11,12,18*); however, see the report by Lassow (*31*). In such cases, the time interval between the before and after (or pre- and posttreatment) measures of ridership provide only short-term elasticities (*4*) that may not accurately reflect long-term elasticities, and therefore may not meet long-term planning needs (*11*). The heart of the problem is the shrinkage ratio, which, when calculated in this way represents a point elasticity, and it is not possible to estimate long-term elasticity from a single point on a demand curve (*7,32*).

Cross-sectional studies suffer from a similar problem: because data are collected for a single point in time, they do not provide an estimate of long-term elasticity (*7,32,33*). Still, cross-sectional models are widely used, despite this drawback, because they usually take into account a broader number of variables (*34*), and the elasticities derived from such models often agree with expectations (*6,11*). However, they have been faulted for failing to provide an estimate of error of the parameter values used in the models, and there is no reason to believe that elasticities derived from current conditions will hold true outside the range of these initial conditions (*11*). Finally, because cross-sectional models are usually derived from survey research, they are, typically, quite expensive to conduct, and they are prone to various sources of error common to this methodology (*19*).

Time series models, using regression analysis, are generally less data intensive and can use data that already exist. Several useful forecasting models, incorporating various combinations of these factors, have been developed in recent years. These models, however, have been designed to model rail ridership (*5,7,8,35*), whereas the majority of mass transit is provided by bus systems. There are two limitations to this type of modeling, according to some planners. The first is that they usually consider only a small number of variables (*34*).

Two problems come into play to limit the number of variables that can be used in regression or time series models. The first problem is the availability of information over a sufficiently long period of time to validate the model. The second problem is multicollinearity (*35*), which means in essence that the independent variables of interest may be so highly correlated that they cannot be used together (*2*). This problem limited the variables used in the models and it raises concerns about the incremental model now used to forecast rapid transit ridership for Honolulu (*27*). Three of the four variables predicted by DBED (i.e., employment, population, and tourists) are so highly intercorrelated only one of them can be used in a given model; entering the others into the model did not improve its predictive ability.

The second criticism of time series regression models is that the aggregate data on which they are usually based do not provide a sufficient level of detail to meet the needs of transit operators (*6*).

The number of variables used in a model is irrelevant if the model is soundly based on economic theory and the model is a good historical predictor. As for the second point, different levels of detail are required for daily operations, project planning, and long-term planning. Long-term planning requires a look at long-term trends, and therefore requires a level of analysis commensurate with this objective. This result is best achieved by using historical data at the aggregate level. Aggregate data have the added advantage of having smaller sampling errors (*19*).

CONCLUSIONS

The economic definition of demand, which states that the quantity demanded of a good is inversely proportional to its price, has been used. Transportation planners sometimes lose sight of this principle, tending to view demand as simply a volume of customers. In keeping with an economic perspective, income would be expected to have considerable influence on demand for transit. This was confirmed by the model, which indicates that the income elasticity for mass transit is negative and, therefore, that mass transit is an inferior good.

Most attempts to measure transit demand rely on cross-sectional studies. This usually entails expensive surveying techniques to collection information on age, sex, income, etc., and using that data to estimate the potential ridership of a particular system. Although every forecasting method has problems associated with it, cross-sectional studies seem to be particularly ill suited for meeting long-term planning needs, because they can provide only short-term elasticities. Ben-Akiva and Morikawa (*19*) have recently indicated how some of the shortcomings of cross-sectional surveys can be compensated for by combining this approach with results from aggregate analyses. Even so, the time and expense of surveys still make them prohibitive. Time series analysis provides an indirect, less costly way of observing consumer behavior by using statistical records of behavior. However, this method, like other nonexperimental methods, suffers from the identification problem. This problem can be overcome by gathering historical data on the major variables likely to affect transit demand and then by using the least squares multiple regression technique to get a fairly good and inexpensive estimate of their relative influence.

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DISCUSSION

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In the introductory section of this paper on empirical research in forecasting transit demand in Honolulu, the authors state that this approach is "well-suited for long-range planning." I would argue that the formulation and variable selection embodied in this model limits its application, at best, to relatively small variations in the existing structure and provision of bus service.

LONG-RANGE PLANNING LIMITATIONS

The Department of Transportation Services (DTS) of the city and County of Honolulu is currently involved in the preliminary engineering stage of the planning and design of a rapid transit system. The model structure outlined by the authors, with size of bus fleet as its only service-related variable, inherently lacks the ability to reflect the improved level of service and corridor capacity provided by this proposed investment. At a practical design level, the model is not sensitive, for example, to variations in alignment or station location. Even at a conceptual level, the unique opportunity for the capture of significant levels of additional (or the latent demand of) non-home based and visitor tripmaking by the rail system cannot be addressed by this approach. Extending this methodology to the analysis and evaluation of a rapid transit system would certainly be neither possible nor appropriate.

STRUCTURAL CONCERNS

Within any mathematical modeling framework (i.e., regression, cross-classification, logit), the inclusion and representation of an explanatory variable must be based on a logical and understandable hypothesis. The authors describe, in some detail, their basis and hypothesis for including each of the four model variables (employment, income, fare, and bus fleet size). However, no discussion is provided to substantiate the use of a natural logarithmic transformation for all of the variables. The net effect of this transformation is to reduce the variation and sensitivity of the changes in each variable over time. Unfortunately, the authors do not include any summaries of observed data for any of the 29 data points (years), and, therefore, it is not possible to examine the properties of the data either before or after their transformation. Even without such information or discussion, use of the natural logarithmic transformation would seem to seriously undermine the analysis.

From a statistical point of view, the authors indicate a rather substantial R^2 value for both forms of the model (i.e., revenue and linked trips). However, it would be beneficial to understand the relative contribution of each variable to the value of this statistic. Beyond employment, does each of the additional variables (income, fare, and size of bus fleet) add to the explanatory power? To what extent are the variables intercorrelated? Alternatively, if the dependent model variable were specified, for example, as annual trips per employee, then would the formulation and statistical results of the regression be of considerably more value?

CAUSAL RELATIONSHIPS

Beyond the mathematical properties of the model, and notwithstanding the limitations apparent for long-range forecasting, the choice of the four model variables themselves provides some concern as well. Although a measure of employment level is certainly an important factor in the choice of trip destination, the choice of mode (specifically, transit) is substantially affected by the density of that employment and the corresponding cost and supply of parking. With only total employment as a key model variable, these additional factors are not considered.

The use of income in the model reflects a level of transit usage that decreases as income increases. However, the 1986 On-Board Rider Survey indicated a rather substantial level of "choice" riders. That is, the choice to use transit in Honolulu goes well beyond the lack of an automobile or, simply, the relative tradeoff between time and cost. In fact, the system carries an atypical number of relatively higher-income passengers.

The single service variable, size of bus fleet, measures the quantity, not the quality, of service. Essentially, regardless of how buses are allocated to the system, the model responds with an identical result. This is because the variable is insensitive to the level of service provided by the competing transit and highway systems.

Finally, the use of fares as the only cost variable ignores the tradeoff between transit fare and automobile (operating and parking) costs.

CONCLUSIONS

Although the empirical research conducted by the authors may be appropriately applicable to generalized policy planning for the existing bus system in Honolulu, particular care needs to be taken in extending the conclusions suggested by the model beyond the explanatory capabilities of the model. Clearly the model cannot be applied in a setting that contemplates the construction of a rapid transit system.

Authors' Closure

We are happy to see that our paper stirred such concern about mass transit ridership forecasts for Honolulu, as evidenced by the immediate response to it (*1*). While our model expressly deals with Honolulu's bus system, we believe that our findings have implications for the fixed-guideway rapid transit system that is proposed for parts of the city.

LONG-RANGE PLANNING NEEDS AND GOALS

We agree with the discussant that our approach is best suited for general policy planning and that it is not applicable at the project level. But his criticisms fail to distinguish between the goals and data needs of long- and short-term methodologies, which we discussed.

The goals of long-range planning are to understand the variables that affect demand for a product and to estimate how changes in these variables will affect future demand. Our models do this by determining the relative influences of key variables on mass transit ridership (demand) in Honolulu and by showing the consequences of future trends (*2*) on transit ridership. As we would not try to deduce from these trends where to place a bus stop, neither would we try to deduce where to put a particular train station. This is a question for the practical design level of project planning, as Davidson acknowledges. From a long-range planning perspective, however, the question is not where to build a train station but whether any should be built at all. The plans for the Honolulu rail transit system ignore significant, local (*3,4*) and national (*5*) transit trends, while their model gets lost in details (*6*).

It is not common practice to publish summaries of raw data and the discussant's complaint that we did not do so not only ignores the fact that the data sources were cited, but that the data are the same as those used by, and (in some cases) come from, the Honolulu Department of Transportation Services (DTS). Because the discussant quotes findings from an unpublished DTS survey, he surely must have ready access to all the data we used in constructing our models.

RELIABILITY OF MODEL FORECASTS

A concern was raised that the data transformations we made could reduce our models' sensitivity to changes in their variables over time. The transformation we used is a standard statistical procedure to linearize regressors (*7,8*) and the almost perfect fit of our model's estimates with actual ridership over a 30-year span, shown in Figure 1 of our paper, attests to the fact that the model is quite sensitive to changes in these variables.

The question of sensitivity should rightly be asked about the DTS model. The DTS model uses the same aggregated employment and population data we used but it disaggregates them into 190 traffic analysis zones (TAZs) for a base year (1985) and a target year (2005). Population and employment within each zone are summed to form a composite variable, and the percentage increase in this composite between the base and target years is used as a growth factor. Transit ridership for the base year is multiplied by the growth factor to estimate ridership for the target year (*6*). Because there are few zones in which the composite decreases, transit ridership is predicted to grow, independent of service and cost. Apart from the potential error in disaggregating the data and the probable impropriety of using this composite, which we discuss in our paper, one might ask how sensitive such a model is to observed changes over time?

Three distinct ridership trends are clear in Figure 1 of our report: a 20.5 percent decrease between 1957 and 1970 (ignoring the strike years); a 150.5 percent increase between 1972 and 1982; and a 1.4 percent decrease from 1982 to 1988. During the same time periods, the employment-population composite increased 50.9, 17.2, and 9.9 percent, respectively. Given the importance assigned to this composite as a growth factor in the DTS model, it is unlikely that it would be able to predict these past ridership trends.

Another statistical criticism was made that we did not provide enough information for the reader to determine the relative contributions of the variables to the models. This is not true. The direction and magnitude of the effects of each variable are provided by the formulas and elasticities, whereas their t and p values indicate that each makes a unique, significant contribution to the model. If it was common practice to list the partial correlation coefficients, we would have included them as well, but doing so would convey basically the same information in different form (*7,8*).

The adjusted R^2 values for the models demonstrate their statistical reliability, and we also presented measures of error for each model. In contrast, DTS provides no measurements of model error, nor has it done a sensitivity analysis to see how the model is affected by different assumptions about population and employment growth. DTS has not even tested the model's basic assumption that population plus employment is a good predictor of ridership.

In order to test this assumption, we summed base year transit trips into and out of each TAZ and regressed these values on the composite population and employment data for each of the 190 TAZs in the base year. The results of this analysis produced an R^2 value of 0.10, which indicates that the composite accounts for just 10 percent of the zonal variation in transit trips. With such a weak association between these variables, it is difficult even to predict base year trips from the base year employment and population data. The error rate of the predicted values, in terms of their mean absolute percentage error (MAPE), was above 120 percent. Is it likely that this model can accurately predict the future?

MODELING AND CAUSAL RELATIONSHIPS

The problem of assigning causality is particularly difficult whenever nonexperimental methods are used, as we discussed at some length in our paper. This, as we explained, is why the explanatory variables we chose were based on economic theory. In the absence of a theoretical framework, any number or manner of variables might be included in a model. Several recent studies point to the importance of transit vehicle size on ridership (*9,10*), yet this variable is not included in the DTS model. How might this variable effect DTS's ridership projections?

We repeatedly noted that bus fleet size provides only a crude measure of service, but it may not be as crude as some would think. Although data on vehicle-miles of service only go back to 1970, from 1970 to 1989 (the last year of our model) the correlation between number of buses and miles of service is $r = 0.93$. Despite the suggestion to the contrary, we examined the affects of automobile costs and availability, but they do not add to the explanatory power of the model; nor does the number of visitors. The suggestion that income must not influence ridership because the bus system has an "atypical number of relatively higher-income passengers" falls under the rubric of the fallacy of composition: i.e., erroneously generalizing from the parts to the whole.

CONCLUSIONS

We certainly do not believe that our models would apply to new and innovative transit alternatives like those being pursued in California and elsewhere. Nor have we advocated that our models be used to forecast ridership for Honolulu's fixed-guideway system. They were intended to model fixed-route, fixed-schedule mass transit, in short, a bus system. Because a fixed-guideway system epitomizes these transit characteristics, however, our models may have more relevance for such a system that we credit them with having.

Our findings regarding the ridership trends of the Honolulu bus system are consistent with forecasts used by Gordon and Willson (*11*) in other cities.

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Unjust Equity: An Examination of California's Transportation Development Act

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Federal subsidies of public transit, particularly transit operations, are declining and the responsibility for supporting transit is falling increasingly on states and localities. In California, the Transportation Development Act (TDA) has become the state's principal source of transit operating subsidies. It is found that the strict per capita allocation formulas of the TDA strongly favor lightly patronized suburban transit service over more heavily patronized service in the central cities. Transit riders in San Francisco, for example, receive a TDA subsidy of $0.13 per trip, whereas the TDA subsidy to transit patrons in suburban Livermore is over $5.00 per trip. The built-in suburban bias of the TDA is the result of partisan compromises made to secure passage of the Act in 1971—compromises to assuage a Republican governor opposed to new taxes—and to include the interests of rural and suburban counties. The result has been a proliferation in California of new, well-funded, and expanding suburban transit operators that attract few riders whereas older, heavily patronized central city transit operators are forced to cut service because of funding shortfalls. This paper concludes by proposing a more efficient and equitable method for allocating TDA funds than the current formula, which, in the name of equity, provides all Californians with a "fair share" of public transit whether or not they use it.

An extraordinary amount has been written about the rise, fall, and (halting) resurrection of urban public transit in the United States. Much of the work on transit's resurrection from the 1960s to date has focused on the significant role federal subsidy programs have had in shaping modern public transit. Productivity declines, increased labor costs, the expansion of service, and the overcapitalization of operations have all been traced to the influence of federal subsidies (*1–4*).

However, for most of the 1980s federal support of public transit has been declining. Federal transit operating subsidies, in particular, have dropped dramatically. Between 1979 and 1987, federal operating assistance was cut 48.7 percent in current dollars; considering the effects of inflation, the drop was nearly 70 percent in just 8 years (*5*).

Table 1 presents a testimony both to the Reagan administration's commitment to federalism in general and distaste for transit operating assistance in particular. Although inflation-adjusted passenger fare revenues and total revenues have grown in concert since 1979, there has been a dramatic shift in operating subsidies from the federal government to states and localities.

California has mirrored this trend toward state and local funding, and the burden of supporting public transit operations in California has been borne largely by the state's Transportation Development Act (TDA). In the 10 years from fiscal year 1978–1979 to fiscal year 1988–1989, inflation-adjusted federal support of transit operations in California decreased 55.7 percent, whereas TDA funding of transit operations increased 32.7 percent in real dollars. Federal funds now account for only 6.1 percent of all transit operating revenues in California, compared to a 24.4 percent share for the TDA. Last year (fiscal year 1988–1989), nearly $500 million in operating funds were allocated to California public transit operators, making the TDA by far the largest source of operating subsidies in the state (*6,7*) and the largest nonfederal public transit funding program in the country (interview with James Mills, Dec. 6, 1990). Even when funding for transit capital (where the TDA plays a comparatively small role) is included, TDA funds accounted for 20.9 percent of all California transit revenues in fiscal year 1988–1989, compared with 19.7 percent for all federal transit funding programs (*6*).

Beyond the sheer magnitude of TDA funding, however, the particular regulations by which TDA funds are allocated have uniquely shaped and—one could argue—distorted the provisions of public transit in California. The TDA has been a boon for suburban transit in California, particularly in affluent counties with low levels of transit ridership. The strict expenditure formulas of the TDA require that funds (which come from the sales tax) be expended in the same county where they are collected. Even within counties, TDA allocations to transit operators are made on the basis of population and not ridership, a method that strongly favors lightly patronized suburban transit operators.

Several authors have noted the role transit subsidies have played in the expansion of suburban public transit (*2,8*). Subsidies have helped keep fares low, and encouraged the growth of flat fares and unlimited ride passes that favor long-distance, suburban commuters (*9*). Wachs (*8*) observed that the growing number of suburban representatives on transit boards and commissions consistently demand increased transit service in the areas they represent:

> Effectively representing their constituencies, who do contribute a growing proportion of transit subsidy support, their advocacy results in systematic shifts of transit service toward relatively expensive and highly subsidized peak-hour runs between suburbs and downtown, and toward relatively lightly used suburban local services.

In California, the suburbanization of transit service is pronounced, politically driven, and primarily the result of the

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TABLE 1 INFLATION-ADJUSTED NATIONAL TRENDS IN PUBLIC TRANSIT OPERATING REVENUES (IN BILLIONS OF 1984 DOLLARS)

Source of Funds	1979 Amount ($)	1979 Percent (%)	1987 Amount ($)	1987 Percent (%)	Percent Change, 1979 to 1987 (%)
Fares	3,218	37	4,315	36	+34
Federal	2,657	31	810	7	−70
State and local	2,752	32	6,794	57	+147
Total	8,627	100	11,919	100	+38

SOURCE: Metropolitan Transportation Commission, Oakland, Calif. (*6,7*).

TDA. This examination of the TDA's effect on public transit in California finds that the compromises necessary to secure the Act's passage have created a politically popular but uneconomic funding program. First, the political debate and subsequent compromises that preceded the passage of the TDA in 1971—compromises that appealed to the partisan, rural, and suburban interests in the state—are traced. A case study of the San Francisco Bay Area is then used to indicate how the TDA allocation regulations dramatically underfund heavily patronized central city transit service in favor of lightly patronized suburban operations. The result is a proliferation of new, well-funded, and expanding suburban transit operators that attract few patrons, whereas older, central city transit operators, in spite of heavy ridership, are forced to cut service because of funding shortfalls. In the name of equity, the TDA is decidedly unfair; the suburban bias ensures that all Californians get a "fair share" of public transit whether or not they use it.

ANTECEDENTS TO THE TDA: CALIFORNIA IN THE EARLY 1970s

California's long-term financial commitment to public transportation was born out of the unique social and political conditions in California of the early 1970s:

- There was broad public concern with air pollution and support for government efforts to improve air quality by reducing dependence on the private automobile;
- The major urban transit operators in California (particularly the Southern California Rapid Transit District) were in financial distress and in need of operating subsidies; and
- The opportunity existed to extend the state sales tax to gasoline and create a substantial new funding source for transportation.

These conditions, discussed in turn in the following paragraphs, combined in 1971 to motivate the passage of the Mills-Alquist-Deddeh Transportation Development Act. This Act extended the sales tax collected by the state to gasoline and earmarked 4.2 percent of sales tax revenues from all sales (¼ cent of the 6-cent state sales tax) for public transportation, community transit services (for the elderly and disabled), and bicycle and pedestrian facilities (under certain conditions, TDA funds can be used for streets and roads); the focus of the TDA, however, was public transit, which received 83.5 percent of the funds allocated for the 1988–1989 fiscal year (*6*).

Air Pollution

Public concern with air pollution grew as urban air quality declined significantly in the postwar years, particularly in the Los Angeles air basin in which vehicle travel increased 268 percent between 1950 and 1970 (*10*) and the early standards of the federal Clean Air Act of 1970 were exceeded over 200 days per year. The foci of early (and most subsequent) air quality regulations were on stationary sources of pollution and emission control devices on new cars. On the demand side, the revival of public transit became the cause *célèbre*; conventional wisdom held that clean, efficient urban transit was needed in California to lure people out of their cars and create a balanced transportation system (interview with William Hein, March 27, 1990).

Funding Shortfalls

The financial distress of California's large transit operators was uniquely shaped by the early years of federal transit subsidies. Federal support of public transit began in 1961 with the passage of the Urban Mass Transportation Act (UMTA). For the first 13 years of the rapidly expanding UMTA program, however, federal transit funds could only be used for the purchase of rolling stock and capital equipment; UMTA funds could not be used to support transit operations. This left transit operators around the country, the Southern California Rapid Transit District among them, without the financial resources to operate an expanding fleet of new, federally financed buses (interview with Arthur Bauer, July 27, 1990). Up to 1974, the federal government clearly saw transit operating subsidies as the responsibility of states and localities (*11*). In California, that responsibility was assumed primarily by the TDA.

New Fund Source

Finally, a financial opportunity existed because the state sales tax, which applied to diesel fuels, did not include gasoline. Extending an existing tax (the sales tax) to a heavily taxed commodity (gasoline) to finance transportation (public transit) was a politically palatable proposal (interviews with Arthur Bauer and James Mills). Turning a palatable proposal into reality, however, required a number of strategic compromises by the Act's legislative authors to appeal to the state's Republican, rural, and suburban interests—compromises that made the TDA heavily biased toward California's more affluent suburbs and against the state's penurious central cities.

TDA AND THE ART OF COMPROMISE

The primary obstacle facing the Democratic triumvirate sponsoring the TDA was a conservative Republican governor (Ronald Reagan) opposed to new taxes. When first approached with the TDA, Governor Reagan wanted the proposal put before the voters. Knowing that it was unlikely that voters statewide would support a measure so clearly intended for central city transit users, Legislators Mills, Alquist, and Deddeh sought to modify the transit sales tax proposal both to satisfy the governor and avoid a plebiscite.

The first step was to technically designate the ¼ cent of the sales tax for the TDA as a "local tax" instead of a state tax. At the time, California had a uniform 5 percent sales tax in all 58 counties (4 percent state, and 1 percent local). When the sales tax was extended to gasoline by the TDA, the state-local split of sales tax was also changed to 3.75 percent state and 1.25 percent local. The additional 0.25 percent local tax, however, was not very local; expenditure of these funds was made subject to state statutes and administrative code of the TDA.

In order to further assuage the governor, each of California's 58 county boards of supervisors voted whether to extend the sales tax to gasoline and accept an additional 0.25 percent of the sales tax for TDA expenditures. The vote, however, did not offer the county supervisors much of a choice. At the time, the California Franchise Tax Board required that the sales tax be uniform in all counties (this has since been changed to allow special county sales taxes for transportation); if a county did not agree to the uniform state sales tax (which was a nickel at the time), then that county forfeited all state-collected sales tax revenues. The county supervisors were thus given a choice whether to extend the sales tax to gasoline and accept an additional 0.25 percent local funds for the TDA, or forgo all local sales tax revenues. Given this choice, it is not surprising that the counties voted unanimously for the TDA and thus satisfied Governor Reagan's desire for a local vote.

Rural and suburban counties, however, were not simply strong-armed into supporting a transit funding program for the central cities. The TDA was fashioned to appeal to the interests of rural and suburban counties. The appeal to rural interests was straightforward; small counties would be permitted to use some of their TDA funds for road projects. Counties with 1970 populations below 500,000 can use TDA funds for streets and roads if the presiding transportation planning agency determines that there are no "unmet transit needs that are reasonable to meet" (*12*). (The unmet needs process was actually added to the TDA later as administrative code because many rural counties were not funding public transit and using all of their TDA funds for streets and roads.) Such determinations are nearly automatic in rural counties and about half of TDA funds collected in these counties (but less than 15 percent of TDA funds statewide) are used for streets and roads purposes.

More important than the rural streets and roads concession, however, are the strict return-to-source provisions in the Act. In order to make the TDA a local tax, the Act creates a Local Transportation Fund (LTF) for TDA funds generated in each county (*12*); because the LTF is a local fund, TDA funds generated in rural and suburban counties cannot be moved across county lines for use by transit operators in urban counties.

The Act further restricts the movement of funds by requiring that revenues be apportioned to transit operators within counties on the basis of service area population only (*12*). [The state's largest county, Los Angeles (LA), is an exception. The apportionment rules for LA County were amended in 1980 to dovetail with the passage of a county transportation sales tax, which, among other things, was intended to hold down transit fares. TDA funds are apportioned to LA County transit operators using a formula that gives 50 percent weight to the ratio of fare revenue to operating cost ratio and 50 percent weight to the operator's share of county-wide transit route mileage (*12*)]. This process means that transit operators are limited (a) to TDA funds generated in the county or counties they serve, and (b) to a share of TDA funds proportional to the ratio of their service area population to the total county population.

Although these return-to-source provisions appealed to the Republican governor and the parochial interests of the county supervisors, they also locked a suburban bias into the TDA in perpetuity. This bias exists because TDA funds are strictly allocated on a per capita basis, but per capita transit ridership varies greatly from city to suburb. Transit use is highest in central city areas where parking is restricted, fewer people have access to automobiles, and employment and population densities are highest; TDA funds, however, do not vary with transit ridership. The result is an extraordinary windfall for transit operators in suburban areas with low per capita levels of ridership; a windfall that is made clear in the following case study of the San Francisco Bay Area.

EFFECT OF THE TDA IN THE SAN FRANCISCO BAY AREA

With a population in excess of 5 million, the nine-county San Francisco Bay Area is the nation's fourth largest metropolitan area. Seventeen major public transit operators and dozens of smaller public and private operators carry over 1.5 million passengers per day on a fleet of almost 4,000 vehicles.

The Bay Area is unique both in the large number of public transit operators and in the absence of a single dominant system. The San Francisco Municipal Railway, the oldest publicly owned transit system in the U.S., comes closest. Muni serves less than 15 percent of the region's population, but carries over half the transit users.

Table 2 presents the Bay Area's 17 transit operators by type. The two central city operators serve the densely settled cities and inner-ring suburbs of San Francisco, Oakland, Berkeley, Richmond, and Hayward. The trunk-line rail operators provide commuter rail service to the five southern Bay Area counties. The large suburban operators serve the extensively developed suburbs of San Mateo, Santa Clara, and Marin Counties. Finally, the small suburban operators provide service in the rapidly developing, far-flung suburbs of Sonoma, Napa, Solano, and eastern Contra Costa and Alameda Counties.

TABLE 2 PUBLIC TRANSIT IN THE SAN FRANCISCO BAY AREA (FY 1987–1988)

	Annual Ridership		Total Operating Cost		Fare Revenue	
	Number	Regional Share (%)	Amount ($)	Regional Share (%)	Amount ($)	Regional Share (%)
Central City Operators						
San Francisco Muni	245,053,000	55.1	236,913,100	31.5	71,287,000	29.7
AC Transit	61,308,000	13.8	122,310,000	16.2	44,278,000	18.4
Trunk-Line Rail Operators						
BART	61,737,800	13.9	167,775,000	22.3	78,474,400	32.7
CalTrain	5,595,900	1.3	25,883,100	3.4	9,119,300	3.8
Large Suburban Operators						
Santa Clara County Transit	35,200,000	7.9	103,348,400	13.7	11,307,300	4.7
SamTrans	18,048,100	4.1	34,543,400	4.6	7,797,500	3.2
Golden Gate Transit	8,784,200	2.0	37,187,200	4.9	13,669,100	5.7
Small Suburban Operators						
County Connection (CCCTA)	3,724,600	0.8	10,670,200	1.4	1,718,600	0.7
Vallejo Transit	1,498,000	0.3	2,118,500	0.3	578,300	0.2
Santa Rosa CityBus	1,267,000	0.3	2,261,100	0.3	502,700	0.2
Sonoma County Transit	771,500	0.2	2,714,800	0.4	551,600	0.2
TriDelta (ECCTA)	460,700	0.1	1,734,400	0.2	170,100	0.1
Napa VINE	439,400	0.1	741,000	0.1	130,000	0.1
Wheels (LAVTA)	395,200	0.1	2,180,900	0.3	125,900	0.1
Union City Flea	393,500	0.1	1,064,700	0.1	145,200	0.1
Fairfield Transit	271,400	0.1	635,800	0.1	113,700	0.0
WestCAT (WCCCTA)	194,100	0.0	925,100	0.1	87,500	0.0
Total	445,142,400	100.0	753,006,700	100.0	240,056,200	100.0

SOURCE: Metropolitan Transportation Commission, Oakland, Calif. (*6,7*).

Nearly $1 billion is spent each year by these 17 Bay Area transit operators, about $750 million of which goes to operations. About $240 million in fares are collected each year; the remaining 68.1 percent of operating costs and 100.0 percent of capital costs are paid with subsidies. All told, in excess of $700 million in transit subsidies are expended in the San Francisco Bay Area each year.

At first glance, the TDA appears to have only a moderate role in the Bay Area. The regional aggregation of subsidies presented in Table 3, however, tends to underrepresent the impact of the TDA in three respects: (a) TDA funds are used primarily for transit operations and play only a small role in capital expenditures; (b) the two trunk-line rail systems—BART and CalTrain—receive virtually no TDA funds (and are excluded from the following analysis); the TDA's major role is in local transit; and (c) the sheer magnitude of San Francisco Muni, which receives less than 15 percent of its revenues from TDA funds, tends to wash out the effect of the Act on the other operators.

Figures 1 and 2 show that the impact of the TDA, however, is far from uniform. Figure 1 shows TDA funds as a proportion of each operator's total operating subsidies and Figure 2 the proportion of total operating costs covered by TDA funds. Figure 1 indicates that for 11 of the 15 operators, TDA funds make up at least half of all operating subsidies. Figure 2 shows that for all but two operators, at least one-third of all operating costs are funded by the TDA.

The transit operators listed in these figures are arranged left to right by the number of passengers carried. Given this arrangement, one could surmise that the big operators simply have a larger pool of financial resources from which to draw, and are thus less dependent on the TDA. This is, however, not the case. Although the larger operators do draw on a wider range of financial resources, they do so out of necessity rather than privilege.

This point can be demonstrated by differentiating dedicated transit funding externally supplied to operators by federal, state, and regional agencies, from discretionary funds that

TABLE 3 SAN FRANCISCO BAY AREA PUBLIC TRANSIT SUBSIDIES (FY 1987–1988)

	TDA		Federal		Other State/Local		
Type	Amount ($)	Percent (%)	Amount ($)	Percent (%)	Amount ($)	Percent (%)	Total ($)
Operations	125,751,544	24.0	30,677,850	5.9	367,773,139	70.2	524,202,533
Capital	3,525,086	2.0	136,444,206	77.0	37,328,808	21.1	177,298,100
Total	129,276,630	18.4	167,122,056	23.8	405,101,947	57.7	701,500,633

NOTE: The vast majority of other operating subsidies in FY 1987–88 came from the BART sales tax ($121,904,000), the San Francisco general fund ($115,656,000), and the Santa Clara County transportation sales tax ($56,585,000).
SOURCE: Metropolitan Transportation Commission, Oakland, Calif. (*6,7*).

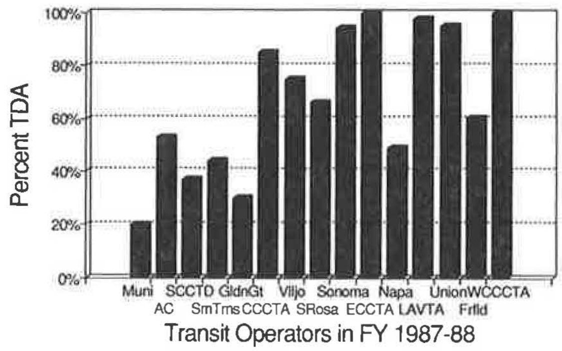

FIGURE 1 TDA as a percentage of total operating subsidies.

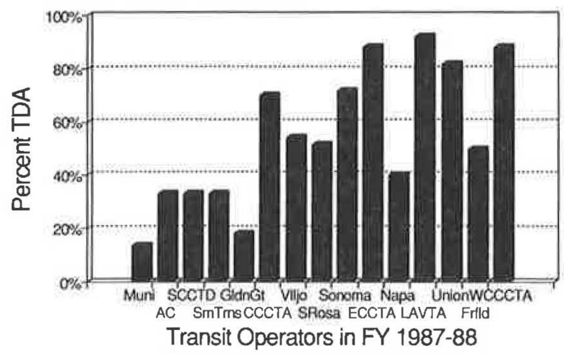

FIGURE 2 Percentage of total operating costs funded by the TDA.

operators must secure locally. For Figure 3, all operating revenues are defined as either external or local. External revenues—federal, state (including TDA), and regional subsidies—are dedicated funds allocated on a formula basis. Local revenues—fares, charter revenues, municipal general funds, local property taxes, and local sales taxes—require a local commitment to transit and can vary quite significantly from year to year. Local revenues require an active financial commitment to public transit at the local level, but external funds are "free"—they are available regardless of the local commitment to transit.

The issue of local commitment is fairly straightforward. In high-transit-use areas like San Francisco, localities have little choice but to devote substantial local resources to transit. In

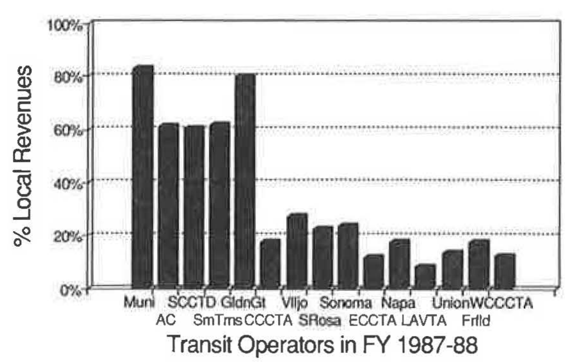

FIGURE 3 Local commitment to transit—revenues from fares and local sources.

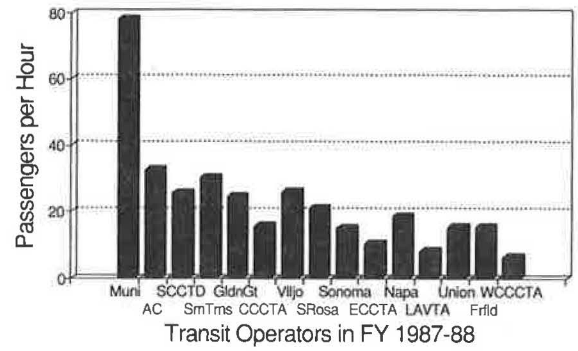

FIGURE 4 Service effectiveness—total passengers per vehicle-hour.

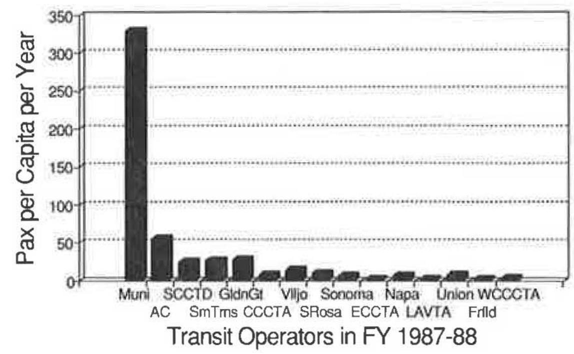

FIGURE 5 Transit ridership per capita by Bay Area operator.

low-transit-use areas, the services can exist almost entirely on external support—primarily TDA funds.

Beyond the gross ridership figures presented in Table 2, the service effectiveness of each operator is shown in Figure 4, using the traditional measure of total passengers per revenue vehicle-hour of service.

The larger operators do not have more riders simply because they have more buses. Ridership per vehicle-hour follows a predictable pattern of decay from densely settled San Francisco to the sprawling suburbs. This pattern is even more sharply contrasted in Figure 5, which shows per capita transit ridership for each operator's service area.

Figure 5 is especially important. Remember that TDA funds are apportioned to each operator on the basis of population, not ridership. Figure 5 indicates that each dollar of TDA subsidy supports 3 transit riders in Livermore and 329 transit riders in San Francisco.

This pattern of TDA apportionments holds within counties as well. Table 4 shows that in Contra Costa Country, for example, four operators—AC Transit, the County Connection, TriDelta and WestCAT—divide the annual TDA apportionment on the basis of service area population. AC Transit, which serves the largest black and low-income areas in the county, has cut service each of the past 4 years to avert a deficit. In each of those years, the County Connection and TriDelta accrued surpluses of TDA funds; the excess funds were added to reserves that now number in the millions for each operator.

(Demographic transit ridership information is limited, but fragmentary evidence suggests that the suburban bias of the

TABLE 4 RIDERSHIP, FARES, AND TDA FUNDS IN CONTRA COSTA COUNTY (FY 1987–1988)

Operator	Annual Passengers		Fare Revenues		TDA Apportionment		Apportionment of TDA per Passenger ($)
	Number	Share (%)	Amount ($)	Share (%)	Amount ($)	Share (%)	
AC Transit	6,297,432	58.8	3,661,952	64.9	2,939,055	20.5	0.47
County Connection (CCCTA)	3,788,700	35.4	1,736,000	30.8	8,002,325	55.7	2.11
TriDelta (ECCTA)	427,700	4.0	166,100	2.9	2,390,046	16.6	5.59
WestCAT (WCCCTA)	189,000	1.8	75,500	1.3	1,034,661	7.2	5.47
Total	10,702,832	100.0	5,639,552	100.0	14,366,087	100.0	1.34

NOTES: The County Connection and TriDelta did not use all of their apportioned TDA funds in FY 1987–1988. The AC Transit figures are for the Contra Costa portion of AC's service area only.
SOURCE: Metropolitan Transportation Commission Oakland, Calif. (*6,7*).

TDA indirectly favors non-Hispanic white transit riders over nonwhite patrons. Combining the TDA revenues, ridership, and ethnic composition of adjacent AC Transit (65.5 percent nonwhite ridership) and the County Connection (39.5 percent nonwhite ridership) indicates that the TDA subsidy per white passenger is $0.79, compared with $0.71 for nonwhite riders. This difference is probably underestimated because of the significant size difference between these two transit operators; demographic data for similarly sized central city and suburban operators would probably reveal an ethnic bias much greater than the 12 percent found here.)

This inverse relationship between service effectiveness and TDA funding is shown clearly in Figure 6, which indicates that the TDA's return-to-source provision allows very high levels of transit funding in low-density, automobile-dependent suburban areas. With funding available, these areas put service on the streets that goes largely unused. The paradoxical effect of TDA funding on Bay Area public transit operations is presented in Table 5.

The clear majority of the region's transit patrons on San Francisco's Muni pay $0.85 fares and receive TDA subsidies of $0.13 per ride, whereas passengers in one of the area's newest suburbs pay $0.60 to board a LAVTA bus and receive a $5.08 TDA subsidy per ride. In the absence of the TDA, the heavily patronized Muni, which receives an annual city general fund contribution nearly four times its TDA apportionment ($164.37 per capita per year), would continue to operate. On the other hand, it is likely that suburban operators such as Wheels (LAVTA), TriDelta (ECCTA), WestCAT (WCCCTA), and the Union City Flea would not exist were not 80+ percent of their costs covered by the TDA.

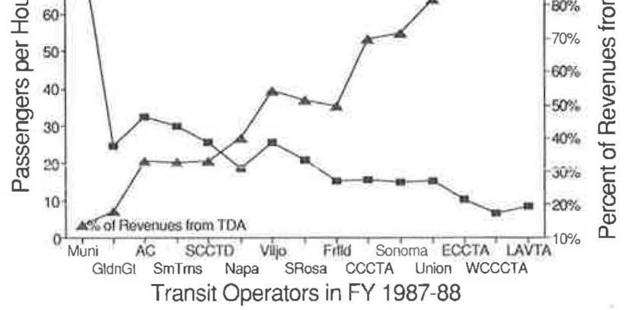

FIGURE 6 A comparative plot of TDA subsidies and service effectiveness.

POLICY RECOMMENDATIONS

When recommending improvements to federal transit subsidy programs, most authors have called for more flexible, performance-based programs that target benefits to the transit user, not the transit operator (*1–3,9,15,16*). The TDA is clearly in need of reform; as currently structured, it is a politically popular, financially wasteful transit subsidy program.

In order to allow greater flexibility, promote improved performance, and target benefits to the transit user, one suggestion would be to match TDA funds to fare revenues; this would encourage operators to set fares and offer service that would maximize fare revenues. Such a program would promote both increased ridership and cost control by rewarding operators for attracting paying customers. Riders would benefit with TDA subsidies proportional to their patronage.

A TDA fare-matching program for local transit operators in the Bay Area is presented in Table 6. This example reallocates TDA transit subsidies for Bay Area operators only; it does not include funds that would be shifted into the region from other parts of the state. The result, as one would expect, is a significant shift in funds from the suburbs to the central city.

The immediate effect of this proposal would be to move funding from unproductive suburban service to heavily patronized San Francisco. Suburban operators would raise fares, which are currently about 40 percent lower than San Francisco Muni or Golden Gate Transit, to increase revenues. In order to retain transit service, suburban areas would have to contribute local funds to the smaller systems and would probably experiment with more cost-effective alternatives to suburban fixed-route service (the five largest Bay Area systems currently receive substantial local funding). More locally generated revenues and less "free" TDA money would encourage suburban operators to focus more on attracting riders and less on operating empty buses. The long-term effect of matching TDA funds to fare revenues would be increased ridership and fare revenues, improved productivity, and improved transit service for the vast majority of transit users.

The likelihood, however, of implementing this or any similar restructuring of the TDA is slim. Wachs (*8*) notes that calls to restructure transit subsidy programs on efficiency and effectiveness grounds do not address the political considerations of subsidy programs and usually fall on deaf ears. Indeed, the motivations to include rural and suburban funding guarantees in the TDA have not diminished in the nearly 20 years since its passage; if anything, statewide politics have grown more parochial since 1971.

TABLE 5 COUNTERVAILING PATTERNS OF TDA FUNDING AND SERVICE EFFECTIVENESS (FY 1987–1988)

Operator	Annual Ridership per Capita	Passengers per Vehicle-Hour	Percent of Operations Funded by TDA (%)	TDA Subsidy per Passenger ($)
Central City Operators				
San Francisco Muni	329.2	78.2	13.8	0.13
AC Transit	56.5	32.5	33.2	0.66
Average	192.8	55.3	23.5	0.40
Large Suburban Operators				
Santa Clara County Transit	24.8	25.5	33.2	0.97
SamTrans	27.8	30.1	33.1	0.63
Golden Gate Transit	28.3	24.6	18.3	0.78
Average	27.0	26.7	28.2	0.79
Small Suburban Operators				
County Connection (CCCTA)	8.5	15.7	70.0	2.01
Vallejo Transit	14.0	25.8	54.3	0.77
Santa Rosa CityBus	9.9	20.9	51.6	0.92
Sonoma County Transit	6.2	15.1	71.7	2.52
TriDelta (ECCTA)	3.3	10.3	88.2	3.32
Napa VINE	7.5	18.6	40.3	0.68
Wheels (LAVTA)	3.0	8.3	92.0	5.08
Union City Flea	7.9	15.3	82.1	2.22
Fairfield Transit	3.0	15.4	49.8	1.17
WestCAT (WCCCTA)	3.8	6.5	88.1	4.20
Average	6.7	15.2	68.8	2.29

NOTES: Golden Gate Bridge Tolls provide 60.5 percent of Golden Gate Transit's subsidies. Vallejo, Santa Rosa, Sonoma, Napa, and Fairfield are in counties that spend TDA funds on streets and roads.
SOURCE: Metropolitan Transportation Commission, Oakland, Calif. (*6,7*).

TABLE 6 PROPOSED REDISTRIBUTION OF TDA FUNDS IN THE SAN FRANCISCO BAY AREA (FY 1987–1988)

Transit Operator	Fare Revenues Amount ($)	Fare Revenues Share (%)	FY 1987–88 TDA Allocation ($)	Proportional TDA Allocation ($)	Percent Change (%)
San Francisco Muni	71,176,000	51.2	17,056,000	56,060,895	228.7
AC Transit	30,124,000	21.7	25,315,000	23,726,795	−6.3
Santa Clara County Transit	11,338,000	8.2	34,313,000	8,930,235	−74.0
SamTrans	7,797,000	5.6	11,563,000	6,141,210	−46.9
Golden Gate	14,444,000	10.4	6,817,000	11,376,637	66.9
County Connection (CCCTA)	1,719,000	1.2	3,788,000	1,353,949	−64.3
Vallejo Transit	555,000	0.4	1,215,000	437,138	−64.0
Santa Rosa CityBus	503,000	0.4	1,236,000	396,181	−67.9
Sonoma County Transit	541,000	0.4	2,113,000	426,112	−79.8
TriDelta (ECCTA)	171,000	0.1	1,581,000	134,686	−91.5
Napa (VINE)	130,000	0.1	296,000	102,392	−65.4
Wheels (LAVTA)	126,000	0.1	2,007,000	99,242	−95.1
Union City Flea	145,000	0.1	984,000	114,207	−88.4
Fairfield Transit	114,000	0.1	306,000	89,790	−70.7
WestCAT (WCCCTA)	87,000	0.1	868,000	68,524	−92.1
Total	138,970,000	100.0	109,458,000	109,458,000	0.0

SOURCE: Metropolitan Transportation Commission, Oakland, Calif. (*6,7*).

CONCLUSION

Although the preamble of the TDA seems unambiguous, "The Legislature hereby finds and declares that it is in the interest of the State that funds available for transit development be fully expended to *meet the transit needs that exist in California*" (emphasis added) (*12*), it is clear that transit needs are defined quite differently in economic and political realms. The TDA is not economic; in the name of fairness, the TDA pours millions of dollars each year into underutilized suburban transit systems around the state, systems that might not exist without TDA funding. In politics, however, the TDA works. In the past, rural and suburban legislators have opposed the shifting of TDA funds across county lines on fairness grounds, and will likely continue to do so.

Although one can argue that a minimum level of transit service should be provided in all parts of metropolitan areas, this examination of California's TDA has shown that ubiquitous metropolitan transit service is an expensive proposition.

ACKNOWLEDGMENT

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Developing Markets for Transit Privatization for Suburban Travel in Large Metropolitan Areas

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A procedure for identifying markets for transit privatization and a case study application are described. The procedure focuses on zone pairs with high travel demand and uses a set of explanatory variables to identify potential markets. Next, these markets are selectively merged to provide a set of viable sectors where transit privatization appears feasible. The procedure was applied on the Detroit metropolitan area to demonstrate its applicability. Initially, over 50 candidate markets for transit privatization for suburban travel were identified that were later narrowed down to 14. These 14 markets, when analyzed in detail, resulted in a total of five sectors where privatization appears feasible. A two-phase survey among local transportation providers was conducted to assess the interest and capability of private providers, and then to match providers with markets identified. The data requirements for the procedure include information on zonal network, land use, and congestion levels. Because most planning agencies are likely to have access to these data, transferability of the procedure to other metropolitan areas does not appear to be a problem.

During the last two decades, the mass transportation industry in the United States has undergone dramatic changes, many brought about by the nation's changing demographics, continued suburbanization, and gradual decentralization of urban activities. Although the relative prominence of the central business district (CBD) as an employment center continued, changing land use patterns were instrumental in the development of major focal points of activities in the suburbs. As a result, the urban travel patterns changed from radial desire lines to widely dispersed movements between many suburban centers to the extent that conventional transit services became ineffective in meeting travel needs.

Concurrently with the problem of changing travel patterns, the transit industry had to face another major crisis: financing. Shortfall in transit operations has grown by a factor of 15 during the last 20 years in spite of modest increases in ridership and in fare-box revenue. The estimated current annual deficit of $4 to $5 billion nationwide is covered by an array of federal grant programs and local and state tax subsidies. In brief, the cost of providing transit services in an environment of diverse travel desires and in an era of shrinking federal subsidies has grown much more rapidly than operating revenues.

The trend toward suburbanization, which started in the late 1950s after the advent of the Interstate highway program, is still continuing. Current estimates are that our suburbs contain approximately half of the U.S. population; this figure is expected to grow to 75 percent by the turn of the century. By the same token, employment opportunities in the suburbs have increased by a factor of two during the last decade; however, few individuals live and work in the same suburb. Other important demographic changes include a reduction in household size, and increases in automobile ownership and in median income. The combined effect of demographic and land use changes has been an overwhelming increase in suburban auto traffic.

The widely diverse travel patterns in our metropolitan centers, along with continued increases in operating expenses have posed serious financial problems to public transportation agencies. Transit agencies in the United States have been hard-pressed to meet the travel demands oriented to the central city, with little resources available to address the emerging travel needs between suburban communities. Privatization is considered by many as a viable tool for improving suburban mobility; however, there are not many examples of successful implementation of such programs in the United States.

On the basis of an analysis of current literature and review of case studies (*1*–3), it appears that the idea of delivering transportation through private contracting for suburban travel is viable provided these options are exercised under the appropriate institutional setting. A recent UMTA report (*4*) reviewed six examples of private sector involvement in four cities (Chicago, Cleveland, Dallas, and Los Angeles) including local business, community groups, major developers, and private providers. The study concluded, "All the cases can be characterized as promising innovation because obstacles both from governmental and the business sectors were overcome as planning processes with broader private sector participation were established."

This study also indicates that although privatization is a viable option, there remains a set of planning, economic, and institutional barriers that must be overcome before privatization receives a more widespread application as a tool for alleviating suburban congestion problems. These barriers include among other factors: lack of an organizational structure to promote privatization at the regional level, lack of any technique to identify markets for transit privatization, and lack of standardized monitoring techniques to ensure quality control of privatized transit services.

This list is by no means exhaustive; however, these represent typical barriers that must be overcome to ensure greater

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application of privatization concepts (*5*). The broad purpose is to develop a procedure for evaluating potential transit markets between suburban centers in large metropolitan cities (*6*). The Detroit metropolitan area was used as a case study site for this proposed methodology. A procedure for developing markets for transit privatization (as developed in that study) is described along with a case study demonstration on a large metropolitan area.

RESEARCH METHODOLOGY

The experience of transit operators in the United States during the 1970–1990 era clearly suggests that it is virtually impossible to provide any type of transit services without public subsidy. Thus, it is unlikely that private sector involvement in the transit market will eliminate the need for subsidy. However, transit privatization may help attain improved quality of service, reduced need for operating subsidies, additional transit demand, and greater interest and participation among the local business community in the resolution of the transportation problem of the community.

This research approach is based on the premise that the prerequisite for a successful transportation program is the identification of specific markets; matching the market, the provider, and specific type of service; and ensuring that appropriate service standards are maintained once the program is implemented. The research approach has four major elements: (a) market identification, (b) assessing the degree of interest among providers, (c) matching markets with providers, and (d) development of operating plans.

A key ingredient to successful private participation is the ability of the transit agency to match unmet travel needs with interested private providers. The first step in this study is the identification of these unmet transit areas. The process of identification includes a review of the travel demand data at a regional level, updating the travel demand to reflect current land use and transportation features and identifying specific production and attraction centers within the study area that are instrumental in generating heavy travel. The journey to work census data, known as the Urban Transportation Planning Package (UTPP), was found to be an important source of information for work trips. The market identification process is built on two important hypotheses: (a) markets for privatization are likely to be those zone pairs that are at the higher end of the demand distribution, and (b) among zone pairs depicting the higher demand, those that represent high congestion levels and longer travel times are likely to be candidates for privatization.

Having identified the potential markets in the study area, the next step would be to place these in order relative to their success potential in privatization efforts. This rank ordering requires the development of a set of criteria and applying the criteria to the candidate zone pairs. An empirically based methodology was developed to rank the candidate zone pairs in terms of their success potential for privatization.

Next, in an effort to assess the degree of interest in participating in privatization efforts, a two-stage telephone survey was conducted among private transportation providers in southeast Michigan. Stage I of the survey was directed toward the development of a data base of potential providers and understanding their capabilities, preferences, and perceptions. Stage II was conducted only among a small subsample of respondents from the first survey and was directed toward obtaining route-specific information. These two surveys are discussed in greater detail in the next section.

The markets identified following these procedures were compared with provider interest in these markets. This process resulted in a subset of the prioritized markets with greater potentials for success because of provider interest. Operating plans for a number of the viable market-provider combinations were developed, including projected ridership, fares, routes, schedules, and fleet size.

DETROIT CASE STUDY

The Detroit metropolitan area was chosen for applying this methodology because it typifies in many ways the changes in land use and travel patterns that characterize today's growing metropolis in the United States. Further, concerted efforts are currently underway by the regional planning agency, the Southeast Michigan Council of Governments (SEMCOG), as well as the regional transit agency Suburban Mobility Authority for Regional Transportation (SMART) to plan and operate public transportation services on a selective basis through private contractors.

Study Area

The Detroit region lies in southeastern Michigan and was ranked as the fifth largest urban area in the United States in 1980 with a population of approximately 5.0 million people. It also ranks as the seventh in terms of population density of urbanized areas. Detroit is the focus of the U.S. automotive industry with the three largest automobile manufacturers having their corporate headquarters within the region. Although it ranks 7th in terms of population, it also ranks 18th out of a total of 20 relative to transit service, as measured by the number of vehicle-miles of transit service per capita, as well as by local transit dollars per capita.

In spite of the lack of transit dominance, public transportation throughout southeast Michigan served more than 77 million riders in 1987. Fixed-route large bus service accounted for the bulk (97 percent) of this service, the remaining 3 percent being carried by a variety of small bus and taxi operation programs, collectively referred to as paratransit services.

Travel Demand Estimation

The first step toward market identification for privatized transit service was an assessment of projected travel demand in the study area for the year 1990. A decision was made at the outset of this project to use work trip (journey to work) data that are available from the census reports through the use of the UTPP files. The decision was based on the premise that the markets for privatization are more likely to be focused around work trips because of the regularity and fixed nature of these trips, as opposed to other types of trips (e.g., shopping) that are more variable both temporally and spatially.

The 1980 UTPP data file for Detroit contained work trip data during the peak 2 hours by specific areal units termed "Traffic Analysis Zones" (TAZs). SEMCOG, as a part of its continuing planning activities, has created a work-trip data base for minor civil divisions (MCDs), by aggregating the TAZs. Further, the three-county study area contained a total of 251 MCDs and a larger number of TAZs. The object of this study being to examine the suburban transit market, a decision was made to exclude from the study the city of Detroit, because the study was not concerned with trips originating at or destined for Detroit.

A total of 41 new areal units, termed as P-zones (abbreviated from privatization zones) were specifically created by combining MCDs. Factors considered in combining MCDs to P-zones included similarity in land uses, geographic proximity, and the general stipulation that the size of a P-zone will not exceed a 6-mi^2 block.

1980 Work Trip Data

A sample of the UTPP file for Troy MCD (P-zone 12), presented in Table 1, indicates that in 1980, a total of 51,526 workers commuted to Troy (a major suburban community in the study area) on an average weekday for work purpose from various MCDs within the study area during the a.m. peak hours. Table 1 presents a number of MCDs that contributed significantly to the work trip destinations in Troy. Similar data for all MCDs in the study area are available in the SEMCOG file. Software was developed as part of this project to convert the UTPP work trip data from the MCD level to the P-zone level on the basis of the following principles:

1. Trips interchanging between MCDs that made up a given P-zone were designated as intrazonal trips.
2. All other trips either originating at or destined to the MCDs comprising a given P-zone were assigned to that P-zone for the purpose of constructing interzonal trips.

TABLE 1 DISTRIBUTION OF DAILY WORK DESTINATIONS TO TROY FROM SEVEN COUNTY COMMUNITIES BASED ON 1980 UTPP PART IV DATA

Home MCD	Daily Workers to Troy	Home MCD	Daily Workers to Troy
Allen Park	109	New Baltimore	25
Avon Twp.	1811	Northville	6
Berkley	660	Northville Twp.	85
Beverley Hills	255	Novi	207
Bingham Farms	9	Oak Park	734
Birmingham	1000	Orchard Lake	36
Bloomfield Twp.	1705	Pleasant Ridge	77
Canton Twp.	153	Plymouth	13
Centerline	138	Plymouth Twp.	25
Chesterfield Twp.	99	Pontiac	615
Clawson	1484	Pontiac Twp.	369
Clinton Twp.	1088	Redford Twp.	292
Commerce Twp.	90	River Rouge	11
Dearborn	278	Riverview	54
Dearborn Hts.	190	Rochester	408
Detroit	4256	Rockwood	29
East Detroit	290	Romulus	12
Farmington	74	Roseville	472
Farmington Hills	691	Royal Oak	4273
Ferndale	998	Royal Oak Twp.	49
Franklin	103	Shelby Twp.	851
Fraser	234	Southfield	1074
Garden City	75	Southgate	45
Grosse Pointe	26	St. Clair	7
Grosse Pointe Farms	164	St. Clair Shores	797
Grosse Pointe Park	152	Sterling Hts.	4627
Grosse Pointe Woods	164	Sylvan Lake	28
Hamtramck	125	Taylor	102
Harper Woods	94	Trenton	25
Harrison Twp.	261	Troy	8944
Hazel Park	690	Utica	167
Highland Park	94	Walled Lake	16
Huntington Woods	107	Warren	3875
Inkster	28	Waterford Twp.	796
Keego Harbor	72	Wayne	10
Lake Angelus	22	West Bloomfield	907
Lathrup Village	109	Westland	143
Lincoln Park	63	White Lake Twp.	131
Livonia	497	Wixom	20
Madison Hts.	2405	Wolverine Lake	37
Marysville	21	Woodhaven	36
Melvindale	37	Wyandotte	64
Mt. Clemens	96	York Twp.	15
Source: SEMCOG and UTPP files		**Total**	51,526

1990 Projected Work-Trip Data

The Fratar technique of growth factor analysis was used to update the 1980 UTPP data base to reflect 1990 conditions using the MINUTP software developed by FHWA. Although more sophisticated techniques for travel demand modeling are currently available, the growth factor technique was used for its simplicity, ease of application, and data availability.

Factors Influencing Potential Markets

The most important factors contributing to the viability of markets were considered to be travel demand, travel time, congestion levels, and land use densities. The relevance of these factors is discussed in the following paragraphs.

Travel Demand

The output of the Fratar model indicated the peak 2-hr travel demand (TD) expressed as number of workers that varied from a low of 0 to a high of 28,500 distributed among the 1,681 cells (P-zone pairs) of the travel demand matrix. The identification of transit markets for privatization is based on the premise that for a market to be viable there must be sufficient travel demand between the two zones. Further, even though much of this demand is met through the use of the private automobile, by adopting proper marketing techniques it is possible to capture fractions of this demand for the transit mode.

In an effort to narrow down the choice of markets from 1,681 zone pairs to a more manageable size, the number of workers commuting between these zones was recast in the form of a frequency distribution in increments of 250. It was found that for 95 percent of the P-zone pairs, travel demand (expressed in the number of workers commuting during the a.m. peak period) was less than 2,500. The remaining 5 percent had their daily a.m. peak demand ranging from 2,500 to 28,500 (Table 2). Because the object of this analysis was to identify high travel demand corridors, the 95 percentile value of the frequency distribution of 2,500 commuters was selected as the cutoff point. Thus, a total of 81 P-zone pairs (5 percent of 1,681 original pairs), being the high travel demand corridors in this area, were identified as the candidate markets.

On further analysis of the candidate markets, it was found that of the 81 P-zone pairs, 28 are intrazonal in nature and 53 are interzonal. A decision was made to concentrate on the 53 interzonal P-zone pairs as more likely candidates for fixed-route transit markets. The 28 intrazonal pairs were eliminated from further considerations, primarily because these trips were not long enough (being intrazonal in nature) to warrant fixed-route services, although these could possibly be candidates for paratransit services. The question of paratransit markets was not explored in this study.

Travel Time Distribution

Next to travel demand, zonal travel time was considered a critical factor in determining potential transit market. It was hypothesized that given a similar travel demand between two zone pairs, a larger portion of the market is likely to be captured by transit from the zone pair with longer travel time. An implicit assumption is that a typical urban traveler is more likely to change his travel mode from the automobile to transit when travel time is excessive.

Congestion Levels

Congestion levels along the major travel corridors for each zonal interchange were also considered a factor contributing to transit market potential. The implicit assumption is that higher congestion levels experienced by the automobile driver would be more conducive to transit travel. SEMCOG, as part of its long-range planning effort, rated each major travel corridor in the Detroit area on congestion ratings of high (H),

TABLE 2 DISTRIBUTION OF TRAVEL DEMAND BY P-ZONE PAIRS

Demand Range	No. of P-Zones/Pairs	% Frequency	Cumulative Frequency
0 - 0	602	38.64	38.64
1 - 250	553	35.49	74.13
251 - 500	128	8.22	82.35
501 - 750	55	5.35	85.88
751 - 1000	35	2.25	88.13
1001 - 1250	22	1.41	89.54
1251 - 1500	21	1.35	90.89
1501 - 1750	24	1.54	92.43
1751 - 2000	9	0.58	93.00
2001 - 2250	11	0.71	93.71
2251 - 2500	17	1.09	94.80
2501 - 2750	8	0.51	95.31
2751 - 3000	4	0.26	95.57
3001 - 3250	5	0.32	95.89
3251 - 3500	8	0.51	96.41
|	|	|	|
|	|	|	|
|	|	|	|
27001 - 27250	0	0.00	99.94
27251 - 27500	0	0.00	99.94
27501 - 27750	0	0.00	99.94
27751 - 28000	0	0.00	99.94
28001 - 28250	0	0.00	99.94
28251 - 28500	1	0.06	100.00

medium (M), and low (L). This rating was based on the percentile distribution of the vehicle miles of travel (VMT) the corridor carried during the peak hours on a given day as a function of a total of 83 major travel corridors in the region (*7*). This information was used to assign congestion levels to the major travel corridors of the candidate transit markets.

Revised Travel Time

Next, travel time and congestion levels were compiled into one composite factor entitled "revised travel time" (RTT). Congestion level, as determined on a qualitative scale of high, medium, and low from the SEMCOG data base, did not directly lend itself to the same level of quantitative analysis as the other two factors, travel time and travel demand. Further, travel time and congestion level essentially depict the same phenomenon, travel impedance. Last, the off-peak travel time as computed from the SEMCOG network data base, did not accurately reflect the relative effect of congestion, because off-peak travel time is computed for free flow traffic conditions. On the basis of these factors, it was decided to increase the travel time on highly congested corridors (rated H) by 50 percent and that on the medium congested (M) corridors by 25 percent. The travel time on corridors with low levels of congestion (L) were considered unaffected by congestion factors. The revised travel times were considered to be depictive of travel congestions during peak hours of congestion.

Land Use Density

It was postulated that zones where activities are clustered together would make better candidates for transit services as opposed to zones where activities are more dispersed. The rationale for this hypothesis was that zones with clustered activities (activities concentrated around one or a few focal points) would lend themselves to a more efficient pickup and drop-off of passengers to minimize walking distance between the bus stop and the trip origin or destination point. By contrast, a zone with dispersed activity patterns would either require many pickup or drop-off points or would result in longer walking distances.

A review of the available land activity data did not result in any indicator variable that could satisfactorily reflect the effect of clustering versus dispersal. As such a decision was made to use density of land activities as a surrogate to clustering with the presumption that higher densities are indicative of greater clustering and vice versa. For each zonal travel interchange, population density (PD) of the origin zone (Zone i) and the employment density (ED) of the destination zone (Zone j) were taken as the surrogate variables.

Priority Ranking of Markets

The 53 candidate markets identified in decreasing order of travel demand in Table 3 were rank ordered using the following variables as discussed earlier: travel demand, revised travel time, population density, and employment density.

Two types of priority ranking techniques were used: The scoring method and the scaling method.

Rank Ordering by the Scoring Method

In this method, a score ranging from 1 to 53 was assigned to each of the four variables, representing the 53 P-zone pairs, a score of 1 being the highest and 53 being the lowest. the algorithm used was as follows:

$$S_i = \sum_{j=1}^{4} W_j X_{ij} \qquad (i = 1 \text{ through } 53;\ j = 1 \text{ through } 4)$$

where

S_i = score of the ith P-zone pair,
X_{ij} = score assigned to the jth variable of the ith P-zone pair, and
W_j = weight assigned to the jth variable.

The software used for developing the final rankings is capable of utilizing any user-specified weights for any variable. Two weighting schemes are reported here. In the first scheme, travel demand being considered the most important variable was assigned the highest weight ($W_1 = 4$) followed by revised travel time ($W_2 = 2$). The two density variables were assigned equal weights of unity. the P-zone pair with the lowest score is to be considered the best by this method. The resulting data of the 53 P-zone pairs are presented in decreasing order of their ranging in Table 4 (Rank 1 considered better than Rank 2).

In Scheme 2, an unweighted ranking was followed (i.e., all variables having equal weights). It was found that there was reasonable correspondence between overall ranking obtained by weighted versus unweighted scheme. This was borne out by the fact that as many as 17 of the first 20 P-zone pairs were common in both the tables. This indicates that overall, the weighting scheme did not significantly affect final ranking.

Rank Ordering by the Scaling Method

By this method, each of the four variables was rated on a scale of 1 to 20, depending on the specific numeric value of the variable. For the purpose of scaling, the range of values for a given variable was divided into 20 equal intervals, so that each interval could be assigned a value ranging between 1 to 20. Thus, each variable for a P-zone pair was assigned a value of 1 to 20; the values were not mutually exclusive because the same value could be assigned for a given variable to more than one P-zone pair. By the same token, a specific value or set of values within the range of 1 to 20 could be missing for a particular variable, depending on its distribution. The algorithm used is as follows:

$$V_i = \sum_{i=1}^{4} W_j S_{ij}$$

where

V_i = scaled value of the ith P-zone pair,

TABLE 3 CANDIDATE MARKETS FOR PRIVATIZATION LISTED BY P-ZONE PAIRS IN DECREASING ORDER OF DEMAND

P-Zone Pairs	Name	Demand (No. of Commuters)	Travel Time in Minutes (and Routes)	Conges-tion Level	Revised Travel Time (min.)
2 - 3	Waterford-Pontiac	14501-14750 (14581)	10.5 (M59)	H	15.75
13 - 21	Sterling Hts.- Centerline/Warren	10501-10750 (10620)	14.25 (M53, Ford Rd.)	H	21.40
32 - 33	Dearborn Hts. - Dearborn Garden City	9751 - 10000 (9889)	12.88 (M153)	H	19.30
22 - 21	East Det. - Warren	9001-9250 (9080)	10.26 (I-94, 12 Mile)	H	15.40
18 - 12	Royal Oak-Troy	8501 - 8750 (8565)	13.46 (I-75, 16 Mile)	M	16.8
14 - 21	Mt. Clemens - Warren	8001-8250 (8222)	18.92 (I-96, 12 Mile)	H	28.4
36 - 33	Southgate-Dearborn	7001-7250 (7217)	13.55 (I-94, Southfield)	M	16.9
31 - 25	Westland - Livonia	7001 - 7250 (7158)	12.22 (I-274 or Newburgh)	M	15.3
13 - 12	Sterling Hts.-Troy	7001-7250 (7126)	15.10 (16 Mile)	H	22.7
36 - 37	Southgate-River Rouge	6251-6500 (6402)	12.79 (I-75)	M	16.0
18 - 17	Royal Oak-Southfield	6251-6500 (6336)	14.14 (12 Mile, Telegraph Rd.)	M	17.7
19 - 17	Ferndale-Southfield	5501-5750 (5534)	13.85 (8 Mile, Telegraph Rd.)	H	20.8
14 - 22	Mt. Clemens-East Det.	5501-5750 (5691)	13.30 (M3, U.S. 25)	M	16.6
21 - 12	Warren-Troy	5251-5500 (5361)	20.55 (12 Mile, I-75)	M	25.7
16 - 17	Farmington-Southfield	5251-5500 (5465)	11.09 (8 Mile, Middlebelt)	H	16.6
38 - 37	Grosse Ile-River Rouge	5001-5250 (5052)	18.87 (I-75)	M	23.6
37 - 36	River Rouge-Southgate	5001-5250 (5033)	12.79 (I-75)	M	16.0
25 - 16	Livonia-Farmington	5001-5250 (5221)	13.72 (Framington or Merriman)	L	13.72
38 - 36	Grosse Ile-Southgate	4501-4750 (4659)	15.76 (Outer Drive)	L	15.76
37 - 33	River Rouge-Dearborn	4251-4250 (4097)	13.81 (Outher Drive, Southfield)	M	17.3
32 - 25	Dearborn Hts.-Livonia	4251-4500 (4362)	14.86 (M153, Inkster)	M	18.6
25 - 17	Livonia-Southfield	4001-4250 (4053)	20.92 (Middlebelt, 8 Mile	M	26.2
23 - 22	St. Clair Shores-East Det.	4001-4250 (4090)	8.26 (Gratiot)	M	10.3
23 - 21	St. Clair Shores-Warren	4001 - 4250 (4053)	14.92 (I-696, M53)	M	18.7
25 - 33	Livonia-Dearborn	3751-4000 (3781)	19,69 (Middlebelt, Ford Rd. on M153)	M	24.6
21 - 22	Warren-East Det.	3571-4000 (3819)	10.26 (8 Mile, M 53)	H	15.4
21 - 13	Warren-Sterling Hts.	3751-4000 (3943)	14.25 (M53)	H	21.4
14 - 13	Mt. Clemens-Sterling Hts.	3501-3750 (3597)	10.18 (Livernois)	M	12.7
5 - 12	Rochester-Troy	3501-3750 (3597)	10.18 (Livernois)	M	12.7
37 - 38	River Rouge-Grosse Ile	3251-3500 (3312)	18.87 (M85)	M	23.6
36 - 38	Southgate-Grosse Ile	3251-2500	15.76	M	19.7
32 - 31	Dearborn Hts-Westland	3251-3500 (3406)	9.34 (Ford Rd.)	M	11.7
31 - 33	Westland-Dearborn	3251-2500 (3461)	16.29 (Ford Rd.)	M	20.4
19 - 18	Ferndale-Royal Oak	3251-3500 (3325)	7.59 (9 Mile)	M	9.5
18 - 21	Royal Oak-Warren	3251-3500 (3474)	15.67 (8 Mile, M53)	H	23.5
10 - 17	Bloomfield Hills-Southfield	3251- 3500 (3396)	16.36 (Telegraph Rd.)	H	24.5
26 - 25	Redford-Livonia	3001-3250 (3210)	11.13 (I-96)	M	13.9
24 - 25	Northville-Livonia	3001-3250 (3223)	16,65 (I-96)	l	16.65
20 - 12	Madison Hts.-Troy	3001-3250 (3144)	11.60 (John R.)	M	14.5
8 - 16	Walled Lake-Farmington	3001-3250 (3198)	23.24 (Pontiac Trail, Haggerty, I-696)	M	29.1
30 - 25	Canton-Livonia	2751-3000 (2889)	16.68 (I-275, I96)	M	20.9
26 - 17	Redford-Southfield	2571-3000 (2969)	15.84 (Telegraph)	H	23.8
12 - 21	Troy-Warren	2751-3000 (2953)	20.55 (I-75, 12 Mile)	M	25.7

TABLE 3 *(continued on next page)*

TABLE 3 *(Continued)*

P-Zone Pairs	Name	Demand (No. of Commuters)	Travel Time in Minutes (and Routes)	Conges-tion Level	Revised Travel Time (min.)
32 - 17	Dearborn Hts.-Southfield	2501-3000 (2737)	25.27 (Telegraph Rd.)	H	37.9
22 - 14	East Det.-Mt. Clemens	2501-2750 (2669)	13.37 (Gratiot)	M	16.7
19 - 21	Ferndale-Warren	2501-2750 (2706)	16.21 (8 Mile, M53)	H	24.3
15 - 16	Novi-Farmington	2501-2750 (2671)	15.73 (I696)	M	19.7
12 - 17	Troy-Southfield	2501-2750 (2647)	23.70 (I-75, 12-Mile)	H	35.6
5 - 3	Rochester-Pontiac	2501-2750 (2643)	12.38 (Rochester Rd., M59)	M	15.5

TABLE 4 PRIORITY RANKING OF 53 CANDIDATE MARKETS BY SCORING METHOD (WEIGHTED)

Rank	P-Zone Pair	Name	Score for each variable TD	RTT	PD	ED	Composite Score (4TD+2RT +PD+ED)
1	14-21	Mt. Clemens-Warren	6	5	16	4	54
2	13-21	Sterling Hts.-Warren	2	19	13	4	63
3	32-33	Dearborn Hts.-Dearborn	3	27	6	1	73
4	21-12	Warren-Troy	15	7	9	6	89
5	13-12	Sterling Hts.-Troy	9	18	13	6	91
6	18-12	Royal Oak-Troy	5	33	3	6	95
7	19-17	Ferndale-Southfield	13	23	1	3	102
8	36-33	Southgate-Dearborn	7	32	11	1	104
9	2-3	Waterford-Pontiac	1	41	21	2	109
10	18-17	Royal Oak-Southfield	11	30	3	3	110
11	22-21	East Detroit-Warren	4	43	5	4	111
12	25-17	Livonia-Southfield	22	6	15	3	118
13	38-37	Grosse Ile-River Rouge	17	15	19	9	126
14	36-37	Southgate-River Rouge	10	38	11	9	136
15	14-22	Mt. Clemens-East Detroit	12	36	16	10	146
16	25-33	Livonia-Dearborn	28	10	15	1	148
17	37-33	River Rouge-Dearborn	21	31	2	1	149
18	31-25	Westland-Livonia	8	45	17	11	150
19	9-17	W. Bloomfield-Southfield	25	13	23	3	152
20	38-33	GrosseIle-Dearborn	31	4	19	1	152
21	16-17	Farmington-Southfield	14	37	20	3	152
22	32-35	Dearborn Hts.-Livonia	20	29	6	11	155
23	23-21	St. Clair Shores-Warren	24	28	4	4	160
24	14-13	Mt. Clemens-Sterling Hts.	29	9	16	14	164
25	37-36	River Rouge-Southgate	18	39	2	13	165
26	21-13	Warren-Sterling Hts.	26	19	9	14	165
27	18-21	Royal Oak-Warren	33	17	3	4	173
28	19-12	Ferndale-Troy	34	21	1	6	185
29	38-36	Grosse Ile-Southgate	19	40	19	13	188
30	25-16	Livonia-Farmington	16	48	15	16	191
31	10-17	Bloomfield H.-Southfield	38	11	26	3	203
32	32-17	Dearborn Hts.-Southfield	48	1	6	3	203
33	23-22	St. Clair Shores-East Det.	23	51	4	10	208
34	31-33	Westland-Dearborn	36	24	17	1	210
35	37-38	River Rouge-Grosse Ile	40	15	2	20	212
36	21-22	Warren-East Detroit	27	44	9	10	215
37	26-17	Redford-Southfield	45	14	7	3	218
38	36-38	Southgate-Grosse Ile	35	25	11	20	221
39	8-16	Walled Lake-Farmington	43	3	27	16	221
40	12-21	Troy-Warren	46	8	18	4	222
41	18-21	Ferndale-Warren	49	12	1	4	225
42	12-17	Troy-Southfield	52	2	18	3	233
43	18-19	Royal Oak-Ferndale	32	52	3	7	242
44	5-12	Rochester-Troy	30	49	25	6	249
45	30-25	Canton-Livonia	47	22	22	11	265
46	24-25	Northville-Livonia	41	25	24	11	269
47	19-18	Ferndale-Royal Oak	39	53	1	8	271
48	32-31	Dearborn Hts.-Westland	37	50	6	21	275
49	26-25	Redford-Livonia	42	27	7	11	280
50	20-12	Madison Hts.-Troy	44	46	8	6	282
51	22-14	East Det.-Mt.Clemens	51	34	5	18	295
52	15-16	Novi-Farmington	50	26	28	16	296
53	5-3	Rochester-Pontiac	53	42	25	2	323

TD = Travel Demand, RTT = Revised Travel Time
PD = Population Density, ED=Employment Density

S_{ij} = scale value assigned to the jth variable of the ith P-zone pair, and
W_j = weight assigned to the jth variable.

The P-zone pair with the lowest scale value is to be considered the best, and vice versa. As in the scoring method, the software used for the scaling method can incorporate any weighting factor as specified by the user. Table 5 presents the result of the application of the scaling method by the weighted scheme (using the same set of weights). As in the previous case, it was found that although for a given P-zone pair, the rankings obtained are different between the weighted and unweighted scheme, overall there was a remarkable correspondence between the weighted and unweighted scores.

Significance Test

The Spearman rank correlation test was used to determine if there is a significant difference between the relative rankings obtained by (a) the scoring versus the scaling method, and (b) the weighted versus the unweighted method. It is a standard statistical technique frequently used for testing the degree of association between two sets of rankings assigned on a number of test objects. The Spearman rank correlation coefficient, r_s, is calculated as follows:

$$r_s = 1 - \frac{6\left(\sum_{i=1}^{n} D_i^2\right)}{n(n^2 - 1)}$$

TABLE 5 PRIORITY RANKING OF 53 CANDIDATE MARKETS BY SCALING METHOD (WEIGHTED)

Rank	P-Zone Pair	Name	Score for each variable TD	RTT	PD	ED	Composite Score (4TD+2RT +PD+ED)
1	2-3	Waterford-Pontiac	1	16	15	1	52
2	32-33	Dearborn Hts.-Dearborn	8	14	5	1	66
3	13-21	Sterling Hts.-Warren	7	14	12	6	74
4	14-21	Mt. Clemens-Warren	11	7	14	6	78
5	18-12	Royal Oak-Troy	11	15	1	6	81
6	22-21	East Detroit-Warren	10	16	4	6	82
7	18-17	Royal Oak-Southfield	14	15	1	2	89
8	32-17	Dearborn Hts.-Southfield	20	1	5	2	89
9	36-33	Southgate-Dearborn	13	15	10	1	93
10	19-17	Ferndale-Southfield	16	13	1	3	94
11	21-12	Warren-Troy	16	9	8	6	96
12	12-17	Troy-Southfield	20	2	15	2	101
13	13-12	Sterling Hts.-Troy	13	16	12	6	102
14	37-33	River Rouge-Dearborn	18	15	1	1	104
15	25-17	Livonia-Southfield	18	9	13	2	105
16	18-21	Royal Oak-Warren	19	11	1	6	105
17	38-33	Grosse Ile-Dearborn	19	7	15	1	106
18	19-21	Ferndale-Warren	20	10	1	5	106
19	19-12	Ferndale-Troy	19	12	1	6	107
20	26-17	Redford-Southfield	20	10	5	3	107
21	23-21	St. Clair Shores-Warren	18	14	2	6	108
22	31-25	Westleand-Livonia	13	16	14	11	109
23	36-37	Southgate-River Rouge	14	16	10	11	109
24	25-33	Livonia-Dearborn	19	10	13	1	110
25	16-17	Farmington-Southfield	16	15	15	2	111
26	9-17	W.Bloomfield-Southfield	18	10	17	2	111
27	28-27	Grosse Ile-River Rouge	16	11	15	11	112
28	37-36	River Rough-Southgate	16	16	1	16	113
29	14-22	Mt. Clemens-East Detroit	15	15	14	11	115
30	10-17	Bloomfield H.-Southfield	19	10	17	2	115
31	32-25	Dearborn Hts.-Livonia	18	14	5	12	117
32	37-38	River Rouge-Grosse Ile	19	11	1	18	117
33	31-33	Westland-Dearborn	19	13	14	1	117
34	12-21	Troy-Warren	20	9	15	6	119
35	21-13	Warren-Sterling Hts.	18	12	8	16	120
36	23-22	St. Clair Shores-East Det.	18	20	2	11	125
37	18-19	Royal Oak-Ferndale	19	20	1	9	126
38	14-13	Mr. Clemens-Sterling Hts.	19	10	14	16	126
39	20-12	Madison Hts.-Troy	20	17	6	6	126
40	21-22	Warren-East Detroit	19	16	8	11	127
41	19-18	Ferndale-Royal Oak	19	20	1	11	128
42	25-16	Livonia-Farmington	16	18	13	16	129
43	36-38	Southgate-Grosse Ile	19	13	10	18	130
44	8-16	Walled Lake-Farmington	20	7	20	16	130
45	5-3	Rochester-Pontiac	20	16	17	1	130
46	38-36	Grosse Ile-Southgate	17	16	15	16	131
47	26-25	Redford-Livonia	20	17	5	12	131
48	22-14	East Detroit-Mt. Clemens	20	15	4	18	132
49	30-25	Canton-Livonia	20	12	17	12	133
50	5-12	Rochester-Troy	19	18	17	6	135
51	32-31	Dearborn Hts.-Westland	19	19	5	18	137
52	24-25	Northville-Livonia	20	15	17	12	139
53	15-16	Novi-Farmington	20	13	20	16	142

TD = Travel Demand, RTT = Revised Travel Time
PD = Population Density, ED=Employment Density

in which D_i = difference between ranks associated with the object i; and n = number of objects (zone pairs).

The criterion for establishing a degree of association was selected as 0.80 to interpret the results. If the value of r_s was above 0.80, it was concluded that there was a high degree of association between the two separate rankings. The correlation test indicated that (a) there is no significant difference between the relative rankings of the stations by the scoring method and the scaling method, and (b) there is no significant difference between the relative rankings obtained by the unweighted versus the weighted schemes.

Provider Survey

The purpose of the survey was to assess the interest among providers of transportation in privatization projects. The population under study included any for-profit providers in transportation in the seven counties in southeast Michigan. The study included two separate surveys that were administered as Phase I and Phase II.

Phase I Survey Method and Results

The objective in Phase I survey was to describe the project to the transportation providers and determine their level of interest in private contracting to provide public transportation services between suburbs. A total of 292 companies were identified and up to five attempts were made to conduct the interview. A business would be included if it was a for-profit main office of a transportation provider in southeast Michigan.

Of the initial 292 companies, 78 did not fit this criteria (being branch offices, nonprofit firms, and out of business since the directory was published). Telephone interviews were conducted with 113 of the 214 firms, for a cooperation rate of 53 percent. Of the remaining 101 firms, 56 refused to participate, and 45 were unavailable after five attempts (passive refusal).

Of the 113 companies that were interviewed in this phase, 86 (76 percent) were interested in providing public transportation services under contract with a public agency. The interested firms provide a variety of services, with charters and demand-response service the most common. The majority of these firms also provide airport and other scheduled services as well as vacation and travel tours.

A variety of options was presented to determine what might make the bidding process even more attractive to all of the firms, including those who initially expressed disinterest. Not surprisingly, most firms would be more interested if they were guaranteed a minimum payment and if outside revenue was provided. More than half of the companies indicated that priority bus lanes would also make bidding more attractive. In order to summarize the results in the Phase I survey, it was found that private operators are generally interested in working with public agencies on contractual transit services; that these operators have at their disposal underutilized vehicular fleet and that with proper incentives, the private enterprise can be attracted to the field of public transportation.

Phase II Survey Method and Results

The objective for Phase II was to target specific markets for the specific suppliers. Twenty companies from Phase I were identified that had the resources and interest in contractual services with the public transportation agency. These companies were provided with 10 potentially high travel demand routes on the basis of initial results of market analysis to determine interest in providing services on them.

The Phase II survey was designed to provide more specific information to those that had expressed an interest in proposed routes. The 20 companies that were interviewed in Phase II were provided with a list of potential routes and asked if they would be interested in providing service along them. Overall, the majority of the firms were interested in providing services along most of the proposed routes.

Not surprisingly, companies are willing to accept a smaller dollar per hour rate if the agency provides the vehicle. Almost all of the firms liked the idea of an incentive clause that would encourage providers to provider better service and generate additional ridership. A majority of firms also agree that a penalty clause that attaches fines and penalties to correct and discipline substandard services would be effective. Almost all of the companies agreed that penalty clauses would be effective in ensuring prompt service, as well as in maintaining a standard in vehicle maintenance.

The Phase II survey confirmed the findings of the earlier survey, with the additional stipulation that given route-specific information, private operators are more likely to provide definitive answers on their role in public transportation. Further, as the following section indicates, the preference and interest expressed by the private sector can be used to develop transit operating plans.

Establishing Potential Markets

Because there was no major difference in the results obtained by weighted versus unweighted schemes, a decision was made to use the results of the weighted scheme for establishing potential transit markets. A review of the top 20 P-zone pairs in Table 4 (scoring method) and in Table 5 (scaling method) revealed that as many as 14 out of these 20 were common in both tables. These common P-zone pairs were then identified as potential markets for privatization.

Operating Plans

The 14 markets were then merged in various combinations on the basis of contiguity of routes to provide a total of nine sectors for privatization. Complete operating plans were developed for five of the nine sectors (including fleet size, headway, speed, fare-box revenue, and operating cost).

The demand data compiled from UTPP files indicated the expected number of workers commuting between P-zones during the a.m. peak two hours. It was also assumed the same number of workers would travel between the same P-zones during the p.m. peak period. The premise of this study is that by providing high-quality transit services, it may be possible to capture fractions of the travel demand market for transit.

On the basis of discussions with local transit agencies and experience in other areas, it was felt that a range of 3 to 15 percent of market capture by transit of the current demand would represent a realistic scenario. Further, it is generally agreed by transit experts that actual market capture by a new transit service is likely to start at a low end; however, service quality becomes the ultimate determining factor of transit ridership over the long run.

The business plan represented in this report is based on a modest market capture of 5 percent of the travel demand for express bus service with no intermittent stop between the P-zones. Table 6 presents data on expected ridership (based on a 5 percent market capture), individual segment lengths for each sector. A review of Table 6 indicates that ridership on Sectors 1, 2, 3, 5, and 7 is reasonably balanced between different segments (P-zone pairs) of these sectors. In Sectors 4, 8, and 9, on the other hand, there is a much greater lack of balance in ridership between different segments. Sector 6 is the only sector that is based on a singular market in one direction with negligible ridership in the reverse direction.

In developing business plans, the computation of size of bus fleet is based on the ridership at the maximum loading section (MLS). A lack of balance in ridership between different segments is likely to reduce the cost-effectiveness of the system, because of the large vacancy rate at the low-ridership segments. Thus, efforts to develop business plans for this project were limited to Sectors 1, 2, 3, 5, and 7 only.

Fleet Size, Headway, and Cycle Time

Using methodologies followed by transit agencies and suggested in textbooks, the fleet size, headway, and cycle times for each of the five sectors were computed (*8*). The following formulations were used in these computations:

$$Nv \geq (Dp \times Q)/(Vc \times 60)$$

$$H = Q/Nv$$

where

- Nv = number of buses required (fleet size),
- Dp = hourly passenger demand at the maximum loading section (MLS),
- Q = cycle time (min) = Td + Ts + Tc,
- Td = driving time (min),
- Ts = boarding and unboarding time (min),
- Tc = layover time (min),
- H = headway (min), and
- Vc = number of passengers by each bus.

As indicated earlier, the value of Dp was taken as the demand at the MLS compiled from information presented in Table 6. The following set of assumed values was used in computing the headway and fleet size.

TABLE 6 EXPECTED RIDERSHIP DATA BY P-ZONE PAIRS FOR NINE SECTORS ON THE BASIS OF A 5 PERCENT MARKET CAPTURE RATE

Sector	P-Zone	Demand (Peak-Hour Ridership)	Distance (miles)	P-Zone	Demand (Peak-Hour Ridership)	Distance (miles)	P-Zone
* 1	14-Mt. Clemens	592	9.44	13-Sterling Hts.	531	7.03	21-Warren
	21-Warren	274	7.03	13-Sterling Hts.	104	9.44	14-Mt. Clemens
* 2	14-Mt. Clemens	696	8.25	22-East Detroit	454	5.38	21-Warren
	21-Warren	268	5.38	22-East Detroit	134	8.25	14-Mt. Clemens
* 3	13-Sterling Hts.	356	7.42	12-Troy	148	11.75	21-Warren
	21-Warren	197	7.03	13-Sterling Hts.			
4	20-Madison Hts.	69	3.69	18-Royal Oak	428	7.17	12-Troy
* 5	18-Royal Oak	176	3.44	19-Ferndale	277	6.28	17-Southfield
	17-Southfield	116	6.28	19-Ferndale	166	3.44	18-Royal Oak
6	25-Livonia	671	6.79	16-Farmington	274	6.92	17-Southfield
* 7	38-Grosse Ile	919	8.6	36-Southgate	320	6.44	37-River Rouge
	37-River Rouge	215	8.32	33-Dearborn			
	33-Dearborn	31	8.32	37-River Rouge	252	6.44	36-Southgate
	36-Southgate	174	8.6	38-Grosse Ile			
	36-Southgate	541	8.26	33-Dearborn			
8	33-Dearborn	495	7.88	32-Dearborn Hts.	70	7.88	33-Dearborn
9	2-Waterford	729	6.25	3-Pontiac	42	6.25	2-Waterford

* Selected for Developing Business Plans

Dp = Hourly demand at the MLS (based on a 5 percent market capture),
Vc = 50 passengers per bus (no standees),
Vm = 30 mph (maximum speed),
Tc = 2.5 to 5.5 min.

It was also assumed that during the off-peak hours the demand would be reduced by 50 percent. Thus, 50 percent of the fleet size of that computed for peak-hour operation would be required for off-peak operation at twice the headway. Last, the most important assumption was that express, nonstop service would be provided between the P-zone pairs with an effort to maintain an average speed between 20 and 25 mph. Local services may provide additional revenue, particularly because they allow a seat to be sold several times. However, the assumption of express, nonstop service is consistent with the presumed existence of markets for zone pairs with longer travel times as explained earlier. The basic operating data compiled for the five sectors are presented in Table 7.

Operating Cost and Revenue Data

Operating cost and revenue were compiled for privatized transit operation for the following scenario using the fleet and headway data presented in Table 7.

> Peak-hour services are to be provided during a.m. two hours (7:00 to 9:00 a.m.) and p.m. two hours (4:00 to 6:00 p.m.). Off-peak hour services are to be provided for seven hours (9:00 to 4:00 p.m.) at twice the peak-hour headway with 50 percent size of fleet. The private contractor will have the complete responsibility of providing buses (seating capacity 50), operating, and maintenance (including vehicle storage) services for a contractual rate of $70 per bus-hour. (Note: This contractual rate was purposely assumed to be higher than the hourly rate quoted by the providers during the survey, to offset unforeseen increases in energy, price, inflation, etc.) The transit agency will have the responsibility of monitoring the contract, collecting fare-box revenue, ensuring proper service level, and developing and enforcing quality standards for a 20 percent overhead. The effective hourly rate for providing services would thus amount to $84 per hour (including overhead). Although fleet size is computed using 100 percent vehicle occupancy at the MLS, a conservative estimate of 70 percent vehicle occupancy was used for computing fare-box revenue. A bus fare ranging from $0.75 to $1.50 per ride was assumed. Services are to be provided for 255 working days per year. Fare-box revenue was computed for four peak hours using the peak-hour ridership data. For seven hours of off-peak operation, fare-box revenue was estimated as 50 percent of peak-period revenue.

Independent of the privatization approach, the costs of the operating services were also derived by the fully allocated cost (FAC) method, a technique increasingly applied by transit agencies when all the cost elements are apportioned into different variables (*8*). The FAC model developed for large buses for the regional transit agency SMART was used to compile operating cost data (*9*):

SMART Agency Model:

$$FAC = \$1.025X + \$21.03Y + \$80{,}516Z$$

where

FAC = annual fully allocated cost,
X = annual total vehicle-miles,
Y = annual total vehicle-hours, and
Z = number of hours required to provide peak service.

The data compiled on operating cost and revenue are presented in Table 8. The annual operating cost derived by the FAC method in all the five cases analyzed is somewhat higher than the cost of privatized operations as computed under the appropriations stated earlier. In all the cases analyzed, deficits are incurred because of a shortfall between operating cost and fare-box revenue. The data presented in Table 8 are based on two conservative assumptions: (a) an hourly rate of $84 of operating cost, and (b) 70 percent vehicle occupancy. Con-

TABLE 7 BASIC OPERATING DATA FOR FIVE PROPOSED SECTORS

Sector	Peak/Off-Peak	Dp (Passengers/ Hour)	MLS (i-j pair)	Headway (II) (minutes)	Cycle Time (Q) (minutes)	Fleet Size (# of buses)	Av. Speed (mph)
1	P	472	13-21	6	96-100	16	20.0
	O	236	13-21	12	84	7	23.5
2	P	433	22-21	6	66-70	11	23.5
	O	217	22-21	12	60	5	27.3
3	P	178	13-12	12	60-70	5	22.5
	O	89	13-12	30	60	3	26.2
5	P	139	19-17	15	60-70	4	16.5
	O	70	19-17	40	60	2	19.5
7	P	503	26-27	5	100	17	28.1
	O	252	36-37	10	80-85	8	33.0

TABLE 8 COMPARISON OF FARE BOX REVENUE AND OPERATING COST

Sector	Fleet Size Peak/Off-Peak	Annual Operating Cost: Hourly Rate Method $84/hour	Annual Operating Cost: Fully Allocated Cost Method	Annual Fare-box Revenue (70% occupancy)	% Profit (Deficit): Hourly Rate Method $84/hour)	% Profit (Deficit): Fully Allocated Cost Method
1	P-16 O-7	$2,420,460	$2,746,595.00	$934,715.25	(61.4%)	(66.0%)
2	P-11 O-5	$1,692,180	$1,872,206.90	$989,068.50	(41.6%)	(66.0%)
3	P-5 O-2	$728,280	$817,742.95	$275,285.50	(48.5%)	(54.1%)
5	P-4 O-2	$642,600	$635,377.40	$347,807.25	(45.9%)	(45.3%)
7	P-17 O-8	$2,656,080	$3,612,311.00	$1,255,212.00	(52.7%)	(65.3%)

siderable reduction in deficit can be attained by reducing the hourly rate for operating cost and increasing the vehicle occupancy. For example, in Sector 1, a reduction in hourly rate from $84 to $45 alone would bring about a reduction in deficit from 61.4 to 27.9 percent.

CONCLUSIONS

The widely diverse travel patterns in our metropolitan centers, along with continued increase in operating expenses, have posed serious financial problems to our public transportation agencies. Privatization is considered by many as a viable tool for improving suburban mobility; however, there are not many examples of successful implementation of such programs in the United States today.

A procedure for identifying markets for transit privatization and a case study application on a large metropolitan area are described. First, a demand-based approach was developed that identifies spatial groups in the study area in the form of zone pairs with high travel demand. A procedure for identifying potential markets from these high demand sectors was identified by considering other explanatory variables, e.g., travel time, congestion levels, and land use density. Third, a procedure for identifying interested private providers was developed through a two-phase survey. Last, operating plans were developed on the basis of an assumed market capture from all available modes by transit service to be provided by the private agency.

This methodology was applied to the Detroit suburban area, focusing primarily on the travel demands between suburban communities in the three-county Detroit metropolitan area. The analysis resulted in a total of 53 candidate markets that were narrowed down to 14 potential markets by two independent priority ranking procedures. These markets were then merged in various combinations to provide a total of five sectors in which privatization of transit service appears feasible. This is further attested by a positive provider response that was conducted as a part of this study.

The data requirements for the proposed procedure include information on zonal travel, network, land use, and congestion levels. Because most planning agencies are likely to have access to this type of information, the procedure appears to be transferable for application at most regional and local levels.

It can be argued that the proposed methodology of market identification does not specifically address the question of user choice between public versus private operation. Because any user preference survey was beyond the scope of the project, the privatization aspect, as used by the authors, is indeed a policy decision, serving as a starting point for the analysis presented. It is the basic premise of this research that high-quality transit services, whether private, public, or privately operated under public control, have a higher potential of penetrating the market that is currently dominated by the private automobile. The authors' justification of associating privatization with these markets is borne out by considerable suggestive evidence in the literature that privatization, because of is competitive environment, is likely to result in higher quality of service.

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Relationship Between Surveyed Behavioral Intent and Actual Behavior in Transit Usage

IRA M. SHESKIN

Just before Miami's Metrorail opened, ridership projections for the system indicated that (depending on pricing assumptions) as many as 202,000 riders might use the system daily. With this in mind, the University of Maryland (UM) planned to undertake expensive improvements next to University Station. In 1983, a pretransit survey was undertaken on the UM main campus to discern the probability that the campus community would use Metrorail. The overall conclusion was that 5,796 persons expressed an intention to access the campus using Metrorail "at least one time per month or less." Applying a rule from the transportation planning literature suggested that 427 persons would take Metrorail to campus on a randomly selected weekday. In 1987, a posttransit survey was conducted at the UM Metrorail station. All persons disembarking Metrorail and entering UM property were counted. Approximately 313 interviews were completed. The results indicate that about 350 persons were riding Metrorail to UM each day in 1987, a number within an acceptable level of error of the 427 persons predicted from the behavioral intent questions on the 1983 survey. An important point is that the student body changed almost completely in the 4-year span. The principal implication is that the rule of dividing by a number between 3 and 5 (4 was used in this study) is an accurate guide even when considering populations that change between the time of a pretransit survey and the institution of the transit service, such as is true with students, the elderly, employees, and other groups.

Most transportation surveys ask a significant battery of questions concerning attitudes toward transportation, attributes of respondents (demographics, automobile ownership, housing type, etc.), and travel behavior. Models are then used to relate attitudes and attributes to travel behavior to predict travel demand. The results of two surveys are reported. The pretransit survey was conducted in 1983, just before the opening of Metrorail in Miami (Dade County). The posttransit survey was conducted in 1987.

Just before Metrorail opened in Miami, ridership projections for the system indicated that (depending on pricing assumptions) as many as 202,000 riders might use the system daily. With this figure in mind, the University of Miami (UM) planned to undertake landscaping and other improvements in the area of the campus next to University Station. Significant discussions also occurred concerning the relocation of certain campus functions to locations closer to Metrorail. Because of the significant expenditures involved in these plans, a pretransit survey was undertaken on the UM main campus in April 1983 of administrators, faculty, staff, and students to discern the probability that each group would take Metrorail to campus. The overall conclusion from this study was that 5,796 persons expressed an intention to access campus using Metrorail "at least one time per month or less." Applying a rule from the transportation planning literature that implies that actual behavior will be one-fourth of expressed behavioral intent, suggested that 427 persons should take Metrorail to campus on a randomly selected weekday.

In 1987, an intercept survey (the posttransit survey) was conducted at the UM Metrorail station. All persons disembarking Metrorail and entering University property were counted as using Metrorail to access the campus. An attempt was made to interview each of these persons. Approximately 313 interviews were completed. Interviewing occurred both on a Tuesday and a Wednesday because class schedules differed between Monday, Wednesday, and Friday, on the one hand, and Tuesday and Thursday, on the other hand. Questions were asked concerning each respondent's status (faculty, student, staff, visitor, etc.), destination on campus, frequency of riding Metrorail, availability of automobile, and possession of a monthly Metrorail pass. Time of the day the trip was made, gender, and race were obtained via observation.

The results of the posttransit survey indicated that about 350 persons were riding Metrorail to UM each day in 1987, a number within an acceptable level of error of the 427 persons predicted from the behavioral intent questions on the 1983 survey. An important point is that the student body changed almost completely in the 4-year span. The principal implication is that the rule of dividing by a number between 3 and 5 (4 was used in this study) is an accurate guide even when considering populations that change between the time of a pretransit survey and the institution of the transit service, such as is true with students, the elderly, employees, and other groups.

BACKGROUND LITERATURE

Much of the previous theoretical basis for this study has been proffered in the work of Ajzen and Fishbein (*1*). Their "Theory of Reasoned Action" assumes that human beings are rational and make systematic use of available information. The ultimate goal of the theory is to predict and understand an individual's behavior. First, the behavior is clearly defined and the determinants of the behavior are examined. Second, the theory assumes that most actions are under volitional control and, that intention to perform a behavior is the im-

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mediate determinant of the action. In order to predict whether an individual will perform a given behavior, they forward the idea that the "simplest and probably most efficient approach is to ask him whether he intends to (perform the behavior)." Although there may not always be perfect correspondence between intention and behavior, they suggest that a person will usually act in accordance with his or her intention.

A person's intention to perform a given behavior is seen as a function of two basic determinants, the personal factor and the subjective norm. The personal factor is the individual's positive or negative evaluation of performing the behavior vis-à-vis the manner in which performing the behavior will affect him personally. This evaluation is affected by a person's behavioral beliefs, that is, their attitude is affected by what they believe will be the result if they adopt the behavior. With respect to modal choice, clearly some individuals will have a positive attitude toward use of a rail system, whereas others would view its use in a negative fashion. The transportation planning literature includes many factors that help to shape these attitudes: trip time, trip length, gender, race, occupational status, income, education, and a host of other geographic and demographic variables.

The second determinant of behavior (the subjective norm) is based on the individual's perception of the social pressures placed on him or her to perform a given behavior. Generally speaking, people are more likely to perform a behavior (or to indicate on a questionnaire that they will perform a behavior) if they view social pressures to do so as positive. These subjective norms are also a function of beliefs, termed normative beliefs. Normative beliefs refer to the beliefs concerning the social pressures that one might feel either to perform, or not perform, a given behavior. In terms of the use of a rail rapid transit system, the social pressures may be viewed as both positive and negative. On the one hand, persons riding rail transit receive positive social gratification because much of society views this as positive from an energy and environment-saving perspective. On the other hand, many persons attach a social stigma to the use of public transit. In the particular case described, the university population may be imbued with some degree of social conscience that may lead to a positive answer to a question about intent to use transit. On the other hand, among students, peer pressure may be strong. Students are in a stage of their life cycle when they are beginning to "strike out on their own" and the automobile is a strong symbol of this independence.

Despite the promise of this theory of behavior prediction, only a minority of travel surveys have asked "behavioral intent questions," in which respondents are queried directly as to whether they intend to use a particular transit service in the future. The extent to which direct questions about intent to use a transit system can be used to predict actual future behavior is examined. Some questions about behavioral intentions might be included in a survey as a procedure for measuring attitudes, or as a way of assessing the outcome of an individual's attempt to combine underlying attitudes with perceived situational exigencies. However, the main purpose of asking questions about behavioral intentions lies in the hope that intentions will act as valid predictors of future behavior. Just as questions about past behavior (via a travel diary, for example) might be used to recover information that would otherwise be unavailable, questions about behavioral intent offer a means to study behavior that is unavailable because it has not yet occurred (ridership on a system before system implementation).

Such exercises at prophesy are bound to be hazardous, however, for even when present intentions are obtained accurately, circumstances can always change in a way that upsets the best-laid plans (*2*). Kelley and Mirer (*3*) and Schwartz (*4*) provide evidence that the gap between behavioral intent and actual behavior widens as the distance into the future of the projected behavior increases. Predictions are more successful when the respondent has direct experience with the kind of act asked about rather than encountering it only as a survey question (*5*). This suggests two things in the current context. First, purely hypothetical questions about intentions are less likely to be useful for prediction than are questions about intentions concerning recurrent events. Thus, if a person has been using public transit for the work trip, a question about continued use of this mode into the future probably will yield a result with a high degree of predictive value. Second, questions about the demand for a mode of transit with which people have previous experience should provide more reliable information than for a new mode. In the current context, respondents were being asked to assess the likelihood that they would ride a new rail rapid transit system with which no one was yet familiar. This, in and of itself, suggests that the predictive value of the behavioral intent questions may be limited.

This assessment stands in contrast, however, to some voting studies. When asked whether one will vote in a given election, many will overstate their propensity to vote to please the interviewer (*6*). But when likely voters are asked for whom they will vote, close correspondence is found between intention and behavior (*7*).

A significant literature exists in which behavioral intention is surmised from questions about attitudes (*8,9*). The strength of the attitude-behavior relationship is shown to vary greatly depending on the topic covered, the time involved, the nature of the measurement of both the attitudes and behaviors, and a wide variety of other factors (*2*).

Two studies from the transportation literature bear directly on the problem to be described. Hartgen and Kreck (*10*) examined the problem of forecasting the probable usage of innovative transportation services, such as dial-a-bus and park-and-ride, in a variety of urban and rural environments. Instead of asking behavioral intent directly, they study current behavior in the city in question as well as behavior in other locales in which the innovative transportation system is already in operation.

The most important study with respect to the current problem is by Couture and Dooley (*11*). Their major conclusion confirms the findings of earlier studies: that reported prior intentions to use a new service often significantly overstate actual use once the service has been implemented (*12*). This overstatement is seen as deriving from respondents' lack of experience with the new mode and from changing attitudes. More specifically, the study concluded that (a) intentions (to use transit) overstate actual behavior; (b) negative intentions are better indicators of nonuse than positive indicators are of use; and (c) situational factors (e.g., automobile and transit accessibility) are important determinants of modal choice. Couture and Dooley (*11*) suggest that actual behavior can be predicted from behavioral intent by dividing behavioral intent by a number between 3 and 5.

As an example, for a proposed bus system in Danville, Illinois, 85 percent of the women in the sample and 71 percent of the men indicated that they intended to use transit. Actually, only 35 percent of the women and 24 percent of the men used it. These results translate into approximately three intenders for every actual user and confirm the assertion that intention overstates behavior. The results also show that 37 percent of those who said they intended to use transit did use it, whereas 84 percent of those who did not intend to use transit in fact did not. Couture and Dooley (*11*) also found that those indicating intent to use transit more frequently were, in fact, more likely to use transit than those indicating that they would be occasional users. This result would imply, for this study, that greater faith could be put in answers implying that a respondent would use the Metrorail system "everyday" over those answering, say, "about two days a week."

MODELING FRAMEWORK

Figure 1 shows the conceptual framework for this study. The major question being asked is the extent to which expressed behavioral intent can predict actual behavior. Behavioral intent may be viewed as affected by attitudes, perceptions, and beliefs, by demographics, by current behavior, and by the level of knowledge that respondents possess of the future system. Respondents' general attitudes toward public transit, their perceptions of its appeal, and their beliefs as to its cost, comfort, and convenience will clearly influence expressed behavioral intent. Previous literature suggests that demographics, particularly age and gender, should have a significant influence on expressed behavioral intent. As well, it seems logical to assume that respondents who are more familiar with a proposed transit system can better judge their likelihood of using the system. Finally, current behavior should act as a reasonable predictor of future transit use: those currently using buses, for example, to access campus are more likely to use rail transit in the future.

Actual behavior is obviously influenced by the same set of factors identified earlier as affecting behavioral intent. Actual behavior also will be influenced by the actual environment in which the behavioral decision is made. Actual behavior continues to be affected by attitudes, perceptions, beliefs, demographics, and the level of knowledge of the system, although this level is likely to be heightened by the opening of the system. The real question is the extent to which these factors can be used to predict actual behavior on the basis of expressed behavioral intent.

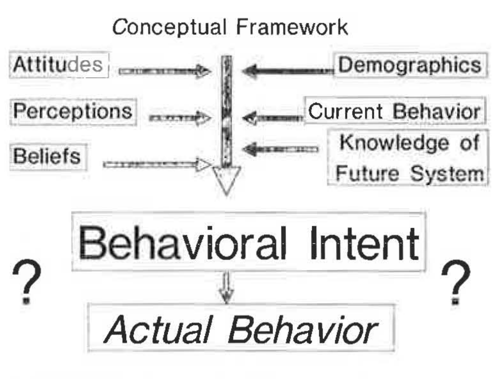

FIGURE 1 Conceptual Framework.

BACKGROUND ON THE METRORAIL SYSTEM

Metropolitan Dade County Florida's Metrorail system is an integrated multimodal public transit system consisting of a 21-mi elevated-rail rapid transit line, a 2.1-mi downtown peoplemover (Metromover), and a bus system originally proposed to expand from 550 to 1,000 vehicles. (This expansion never occurred.) The rail line runs from the expanding Dadeland Shopping Center in the south, past UM to the western fringe of the central business district (CBD), where it connects to Metromover. From the CBD, the line proceeds north to the UM Medical School, through Liberty City, and into Hialeah.

Just before Metrorail opened in Miami in 1984, ridership projections for the system indicated that (depending on pricing assumptions) as many as 202,000 riders might use the system daily. When the system first opened, 6,000 to 8,000 passengers per day were reported; by 1989, the number had increased to about 35,000 per day. Although an analysis of the reasons for the failure to attract the projected number of riders is beyond the scope of the current research, it is important to realize when examining the results reported in the following sections that ridership on the entire system is dismal.

METHODOLOGY

The results of two surveys are reported. The pretransit survey was conducted in 1983, just before the opening of Metrorail in Miami (Dade County). The posttransit survey was conducted in 1987.

1983 Pretransit Survey

With the 202,000 riders per day projection in mind, UM planned to undertake improvements in the area of the campus next to University Station. Because of the significant expenditures involved in these plans, a pretransit survey was undertaken on the UM main campus in April 1983, of administrators, faculty, staff, and students, to discern the probability that each group would take Metrorail to campus. A questionnaire was developed, using a feedback process involving two review cycles including various faculty and administrators. It was then pilot tested with three geography classes. It was also reviewed by knowledgeable Dade County personnel, leading to a questionnaire in which five types of questions were asked: travel to and from campus, parking, midday travel, potential Metrorail usage, and questions identifying the respondent as to employment status, gender, and student status.

Five campus user groups were identified: faculty, students, staff, administrators, and visitors, although no attempt was made to obtain information from the final group. It was decided to undertake a blanket sample of all faculty, administration, and staff both for political and logistical reasons. Such was not so for the 13,000 students. Here, a random sample of 70 class sections of the 2,748 offerings was selected and a blanket sample done in each randomly selected class section. Overall, at least a 62 percent response rate was achieved from the nonstudent groups; 100 percent of the students cooperated. Only for part-time faculty was the response rate unsatisfactory. Note, however, that one possible bias introduced by nonresponse is that nonrespondents may be less likely to ride than respondents. For this reason, the pretransit survey may be expected to overestimate ridership.

Because of the differing response rates among user groups and because students were sampled only at a 5.5 percent rate, weighting factors were devised so that the reported university-wide results properly reflect the relative sizes of the different user groups presented in Table 1.

The questions concerning behavioral intent provided a range of options, and some suggested frequencies for what was then considered the most likely scenario. Optimally, more scenarios and more frequency choices might have been presented. Yet, the practical aspects of survey research suggested to the survey designers that only a limited number of questions could be asked without trying the respondents' patience.

1987 Posttransit Survey

In 1987, an intercept survey (the posttransit survey) was conducted at the UM Metrorail station. All persons disembarking Metrorail and entering university property were counted as using Metrorail to access the campus. An attempt was made to interview each of these persons. Approximately 313 intercept interviews were completed. Interviewing occurred on both a Tuesday and a Wednesday, because class schedules differ between Monday, Wednesday, and Friday, on the one hand, and Tuesday and Thursday, on the other. Questions were asked concerning each respondent's status (faculty, student, staff, visitor, etc.), destination on campus, frequency of riding Metrorail, availability of automobile, and possession of a monthly Metrorail pass. Time of the day the trip was made, gender, and race were obtained via observation.

An important issue is related to the fact that 4 years elapsed between the pretransit and posttransit surveys. Clearly, over this 4-year period, almost all the student body changed, as did a good portion of the administration, faculty, and staff of the University. Thus, the sampling universe for the pretransit survey is different from the universe for the posttransit survey. This change in universe may help explain any differences between the expressed behavioral intent of the pretransit survey and the observed behavior of the posttransit survey. Although this argument is reasonable, it is more than balanced by the fact that while the individuals had changed, the students, as a group, did not change significantly during this period.

More important, this situation (of a changing population between the time of a survey and the implementation of a transit program) is not unique to a student population. Certainly, the time delay between surveying employees for a vanpool or carpool program and the implementation of such a program also may be considerable. The actual population whose behavior would be measured by the postvanpool survey will have changed because of employee turnover. A second example of this situation can be illustrated with the planning of Metrorail itself. Between the time data collection first began (1964 Miami Urban Area Transportation Study) and the completion of Metrorail (1984), the Dade County population increased from less than 1 million to over 1,700,000. Also, it is not difficult to believe that (given that about 20 percent of Americans move each year) many of the 1 million persons in residence in 1964 were no longer Dade County residents in 1983. Similar figures probably could be cited for many major transit systems. Thus, the idea of a changing universe between data collection and project implementation is probably the norm rather than the exception.

One potential problem was that different methodologies were used in the pre- and posttransit surveys. Thus, differences in the results of the two surveys could be related to differences in the methodologies. Finances, however, made it impossible to repeat the 1983 effort in 1987. In addition, observing 1987 behavior may lead to a more accurate ridership estimate than sampling respondents. Unfortunately as well,

TABLE 1 CAMPUS POPULATION AND RESPONSE RATES

User Group	Coral Gables Campus Population	% of Campus Population	Number of Surveys Returned	Response Rate
Graduate	3,617	22.7%	153	100%
Undergraduate	9,469	59.5	557	100%
Student Total	13,086	82.2	710	100%[a]
Staff	1,500	9.4	1021	68.1%
Administration	350	2.2	272	77.7%
Full-time Faculty	750	4.7	426	56.8%
Part-time Faculty	238	1.5	42	17.6%
Total	15,924[b]	100.0%	2,471	

[a]All students asked to cooperate did. The 710 responses is a 5.4% random sample of all students.

[b]Accounting for vacation and sick leave and the number of days per week people come to campus imply 14,600 persons coming to campus each day, exclusive of visitors.

the 1987 methodology did not allow for collections of demographics comparable to the 1983 survey.

Note as well that the posttransit survey was only completed for 2 days and that some possibility exists that these 2 days were not representative. Optimally, a larger sample of days might have been included. Two factors seem to obviate the need for a larger sample of days. First, Dade County ridership figures indicated little daily variation in boardings at the UM Metrorail station. Second, the numbers of riders observed on each of the two sampled days were almost exactly equal.

RESULTS OF THE PRETRANSIT SURVEY

Because the pretransit survey was to be administered to faculty (who constantly complain about demands on their time) as well as to students at the beginning of classes, it became imperative to minimize the length of the questionnaire. Thus, questions designed to predict behavior on the basis of attitudes, perceptions, beliefs, and level of knowledge of the proposed system were not included. Rather, questions were limited to an examination of current behavior, to questions of behavioral intent, and to just two demographic-type queries.

Current Travel Behavior

This section summarizes some major findings of the study, with respect to current travel behavior, which convinced the author (*13*) to treat the behavioral intent results with some degree of conservatism. Table 2 indicates that 91.5 percent of the UM community arrived on campus by car, with the majority (88 percent) parking on campus. Only 1.5 percent used the bus to get to campus on the day on which they completed the form. Table 3 indicates that only about 4 percent used a bus even as few as 20 times in a year; 83 percent had never used a bus to access campus in the past year. Table 4 indicates that even half those persons who did not use a car to access campus did, in fact, have a car available; Table 5 indicates that 90 percent of the UM community possess a driver's license. None of this portends well for rapid transit: most transportation surveys indicate that a good portion of transit riders are "captives," i.e., they have no other options except transit (*14*). This is not so for the UM community. In addition, the 11 percent of the UM community who carpool to campus (Table 6) are less likely to switch to transit because they already enjoy a somewhat inexpensive group journey to school.

Table 7 indicates that, unlike most large employment centers, only 45 percent arrived during the morning peak period (7:00 to 9:00 a.m.); only 28 percent left in the evening peak (4:00 to 6:00 p.m.) (Table 8). The implication of this information is that much of the UM population traveled during the off-peak period, when rapid transit headways are greatest and road traffic is lightest.

Table 9 indicates that 71 percent of the campus community spent 6 min or less finding parking. 80 percent were within a 6-min walk of their first building destination on campus (Table 10). Thus, a serious parking problem that would certainly encourage transit usage (as it does in many CBDs) did not exist on the UM campus.

One aspect of current behavior that did portend well for Metrorail usage is the percentage of persons (49 percent)

TABLE 2 HOW DID YOU GET TO THIS CAMPUS TODAY?

Mode	Faculty	Student	Staff	Administration	Total
Car—parked	88.1%	89.4%	77.4%	88.6%	87.8%
Car—dropped off	3.7	2.2	12.8	4.7	3.7
Walk	2.5	3.9	2.1	1.6	3.5
Bus	1.6	1.1	4.2	2.7	1.5
Other	4.1	3.4	3.5	2.4	3.4
Total	100.0%	100.0%	100.0%	100.0%	100.0%

TABLE 3 HAVE YOU TAKEN METROBUS TO OR FROM THIS CAMPUS IN THE PAST YEAR?

Frequency	Faculty	Student	Staff	Administration	Total
Never	87.0%	83.1%	79.0%	85.1%	83.0%
1 - 2 times	7.4	5.0	6.9	5.2	5.3
3 - 10	3.6	6.7	4.6	3.3	6.2
11 - 20	.2	1.5	1.1	.0	1.4
More than 20	1.8	3.7	8.5	6.3	4.1
Total	100.0%	100.0%	100.0%	100.0%	100.0 %
Summary: 1+ times	**13.0%**	**16.9%**	**21.0%**	**14.9%**	**17.0%**

TABLE 4 DID YOU HAVE A CAR AVAILABLE TO COME TO THIS CAMPUS TODAY?

	Faculty	Student	Staff	Administration	Total
Of Those Not Using a Car Today:					
No	22.1%	45.5%	79.5%	52.9%	48.9%
Yes	77.9	54.5	20.5	47.1	51.1
Of All Persons, Whether They Used a Car Today or Not:					
No	1.8	3.8	7.8	3.5	4.1
Yes	98.2	96.2	92.2	96.5	95.9

TABLE 5 DO YOU HAVE A DRIVER'S LICENSE VALID FOR USE IN FLORIDA?

	Faculty	Student	Staff	Administration	Total
No	9.3%	9.6%	15.7%	4.8%	10.1%
Yes	90.7	90.4	84.3	95.2	89.9

TABLE 6 DID YOU (WILL YOU) CARPOOL WITH SOMEONE TODAY?

	Faculty	Student	Staff	Administration	Total
No	94.3%	89.7%	83.3%	90.9%	89.3%
To & From Campus	5.0	7.0	11.8	7.1	7.4
To Campus	.4	1.9	2.9	.8	1.9
To Leave Campus	.4	1.4	2.0	1.2	1.4
Total	100.0%	100.0%	100.0%	100.0%	100.0%

TABLE 7 APPROXIMATELY WHEN DID YOU ARRIVE ON CAMPUS TODAY?

Time	Faculty	Student	Staff	Administration	Total
Before 9 AM	58.9%	35.9%	79.8%	81.1%	44.6%
9 AM - Noon	32.9	44.5	6.7	12.5	38.0
Noon - 4 PM	6.6	6.8	4.5	5.6	6.3
4 PM - 6 PM	.6	10.0	3.2	.8	8.1
After 6 PM	1.1	2.8	5.8	.0	2.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

TABLE 8 APPROXIMATELY WHEN DID YOU EXPECT TO LEAVE THIS CAMPUS AT THE END OF YOUR UNIVERSITY DAY?

Time	Faculty	Student	Staff	Administration	Total
Before 9 AM	2.8%	1.8%	6.6%	1.6%	2.4%
9 AM - Noon	2.7	5.8	.3	.0	4.7
Noon - 4 PM	19.3	32.6	16.0	3.5	28.6
4 PM - 6 PM	49.7	18.8	63.8	70.2	28.3
After 6 PM	25.5	41.0	13.3	24.7	35.9
Total	100.0%	100.0%	100.0%	100.0%	100.0%

TABLE 9 HOW MANY MINUTES DID IT TAKE YOU TO FIND A PARKING SPACE TODAY?

Time	Faculty	Student	Staff	Administration	Total
0 - 3	83.0%	45.0%	81.0%	81.4%	53.0%
4 - 6	8.1	20.5	11.5	9.1	18.0
7 - 10	4.2	13.2	5.8	3.5	11.3
11 - 20	3.2	12.7	1.3	3.5	10.5
Over 20	1.5	8.7	.4	2.3	7.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Summary: < 6 min	**91.1%**	**65.5%**	**92.5%**	**90.5%**	**71.0%**

TABLE 10 HOW MANY MINUTES DID IT TAKE YOU TO WALK FROM THE CAR TO THE FIRST BUILDING YOU WENT TO ON CAMPUS?

Time	Faculty	Student	Staff	Administration	Total
0 - 3	69.7%	31.7%	71.5%	70.2%	40.8%
4 - 6	22.9	44.0	21.5	24.8	39.0
7 - 10	5.8	18.5	4.7	4.6	15.4
11 - 20	1.5	4.7	1.9	.4	4.0
Over 20	.0	1.0	.4	.0	.8
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Summary: < 6 min	**92.6%**	**75.7%**	**93.0%**	**95.0%**	**79.8%**

indicating that they leave the campus and return at least one time at some point during the day (termed a "midday trip") (Table 11). Questions about the destinations of these trips led to the conclusion that at least 38 percent of such trips could be made by Metrorail (in that they are to destinations that are accessible by Metrorail). Table 12 indicates that 25 percent of the midday tripmakers would have used Metrorail for their midday travel had it been available on the survey day. On the other hand, Table 13 indicates that 89 percent of midday trips are made currently by car, implying that about 44 percent of campus personnel leave campus by car during the midday—many to locations that are not accessible to Metrorail. Certainly, persons who need their car for travel during the day are less likely to leave their car behind in the morning and use Metrorail.

Overall, the questions concerning current travel behavior suggested that ridership of Metrorail by the UM community could not be expected to be significant.

Behavioral Intent to Use Metrorail

Table 14 presents the results of a question with a series of conditions that were, at the time the questionnaire went to print, the Dade County staff recommendations for Metrorail pricing. (The adopted fare was, in fact, $1.00 each way and parking was free during the 1987 posttransit survey.) Table 14 indicates that approximately 31 percent of the UM community expected to use Metrorail; 11 percent would use it "once a month or less"; 10 percent, "1–7 times per month"; 5.4 percent, about twice per week; and 4.4 percent, "everyday." Behavioral intent is certainly much higher among student groups (34 percent planning to use it at least "once a month or less") than nonstudent groups (18 to 20 percent). Note as well that, of those persons expressing an interest in riding 36 percent would use it "once a month or less"; 32 percent, "1–7 times per month"; 17 percent, about twice per week; and 14 percent, "everyday."

TABLE 11 HAVE YOU LEFT THIS CAMPUS AND RETURNED (OR DO YOU EXPECT TO LEAVE THIS CAMPUS AND RETURN) ANY TIME TODAY?

	Faculty	Student	Staff	Administration	Total
No	61.8%	50.0%	58.6%	28.6%	51.1%
Yes, once	31.8	41.1	36.3	52.8	40.3
Yes, 2+ times	6.5	8.9	5.1	18.6	8.6
Total	100.0%	100.0%	100.0%	100.0%	100.0%

TABLE 12 IF METRORAIL WERE AVAILABLE TODAY, WOULD YOU HAVE USED IT FOR THIS MIDDAY TRIP?

	Faculty	Student	Staff	Administration	Total
No	82.5%	72.4%	83.7%	81.1%	74.1%
Yes	17.5	27.6	16.3	18.9	25.9

TABLE 13 WHAT MEANS OF TRANSPORTATION DID YOU (WILL YOU) USE ON YOUR MIDDAY TRIP?

Mode	Faculty	Student	Staff	Administration	Total
Car	84.0%	76.1%	74.1%	79.2%	76.5%
Car pool	10.8	12.2	15.3	8.3	12.3
Walk	1.9	6.5	2.7	8.9	6.0
Bus	.0	1.6	4.8	1.0	1.8
Other	3.3	3.5	3.1	2.6	3.4
Total	100.0%	100.0%	100.0%	100.0%	100.0%

TABLE 14 SUPPOSE METRORAIL OPENS JANUARY 1, 1984; THE PRICE OF GAS REMAINS AS IT IS NOW; METRORAIL COSTS $2.00 ROUND TRIP, PLUS 25 CENTS FOR TRANSFERS TO AND FROM THE BUS; PARKING AT A METRORAIL STATION IS $1.00/DAY. WOULD YOU USE METRORAIL TO GO TO AND FROM THIS CAMPUS?

Frequency	Faculty	Student	Staff	Administration	Total	Total[a]
Never	80.3%	66.1%	82.7%	82.0%	69.0%	
1/month or less	6.8	12.4	4.5	4.8	11.1	35.8%
1 - 7 times/month	5.3	11.3	3.9	4.4	10.0	32.2
2X/week	3.5	5.9	3.5	1.5	5.4	17.4
Every Day	4.1	4.2	5.4	7.4	4.4	14.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[a]Excluding persons never riding. Thus, the interpretation is that 35.8% of persons who indicated that they will ride indicated that they will ride 1/month or less.

Table 15 presents behavioral intent to use Metrorail under various pricing structures. Note that as the total cost (round trip fare plus parking) increases from $1.00 to $2.00 to $3.00 to $3.50 to $4.00, intended usage decreases from 50 percent to 40 percent to 20 percent to under 5 percent. Thus, the campus community—particularly the students—appears to be price sensitive.

On the basis of the literature review and the generally negative indications about future transit use that arise from the study of current campus travel behavior, projected behavior was put at 25 percent of behavioral intent. Table 16 indicates that at a $2.00 total cost, 5,796 UM persons expressed an intent to use Metrorail "at least one time per month or less." Projected behavior was, then, that 1,449 persons would use Metrorail "at least one time per month or less."

Given that 1,449 were to use Metrorail in a given month, calculations of how many of these persons one should expect to encounter on a random selected day are presented in Table 17 and indicate that we should expect 427 riders per day.

Demographic Variables

Space on the questionnaire precluded the inclusion of many demographic variables. In addition, the variance in age for students is minimal. Only two demographic variables were included. The first was occupation. Table 14 indicates that expressed behavioral intention does vary significantly between students (66 percent never) and the other groups (80 to 82 percent never). Finally, in a result not in a table, 5 times as many males as females expressed intent to use the system, suggesting a concern with safety.

RESULTS OF THE POSTTRANSIT SURVEY

The results of the posttransit survey indicated that only about 350 persons were riding Metrorail to the UM each day in 1987, a number that is within the same ballpark as the 427 figure projected by the Couture and Dooley (*11*) rule. This

TABLE 15 IF INSTEAD, THE ROUND TRIP COST (INCLUDING METRORAIL FARE, BUS TRANSFERS, AND PARKING) WAS $1.00, $2.00, $3.00, $3.50, OR $4.00, WOULD YOU USE METRORAIL?

Round Trip Cost	Faculty	Student	Staff	Administration	Total
$1.00	32.4%	54.5%	32.5%	29.7%	50.4%
$2.00	26.3%	43.0%	24.4%	21.6%	39.7%
$3.00	12.9%	21.4%	12.8%	13.3%	19.8%
$3.50	11.1%	8.9%	6.6%	10.5%	8.9%
$4.00	6.5%	4.8%	3.4%	2.7%	4.7%

TABLE 16 BEHAVIORAL INTENT AND PROJECTED BEHAVIOR—NUMBER OF USERS

	Behavioral Intent		Projected Behavior	
Round Trip Cost	% Yes	# Users	% Yes	# Users
$1.00	50.4%	7,358	12.6%	1,840
$2.00	39.7%	5,796	9.9%	1,449
$3.00	19.8%	2,891	5.0%	722
$3.50	8.9%	1,299	2.2%	325
$4.00	4.7%	686	1.2%	172

TABLE 17 PROJECTION OF DAILY RIDERSHIP

Frequency	Percentage	# of Users	Project Daily Riders
1/month or less	35.8%	524	24[a]
1 - 7 times/month	32.2	467	96[b]
2X/week	17.4	252	101[c]
Every Day	14.2	206	206[d]
Total	100.0%	1,449	427

[a]Assumes that about 22 weekdays exist per month. 524 divided by 22 = 24.
[b]Assumes that each person average 4.5 times per month. 4.5/22 of 467 = 64.
[c]Assumes that each person rides 40% of the time (2 of 5 weekdays). .4 times 252 = 101.
[d]Assumes that each person rides each day.

is certainly an encouraging result and suggests that survey research can be used as an effective tool for making ridership projections, even in instances when the population of interest changes significantly between the time of the survey and the implementation of the transit system.

Several additional findings are of interest:

1. Of the 350 riders, 70 percent were students, 13 percent were staff, 12 percent were administrators or faculty, and 6 percent were visitors to campus. This finding is consistent with the pretransit survey, which indicated that a greater percentage of students were likely to use the system.
2. 60 percent rode Metrorail daily and 87 percent rode Metrorail both to and from campus. This is consistent with the idea that behavioral intent is more reliable for respondents who indicated that they would ride everyday.
3. 42 percent had a car available.
4. 54 percent were males. This is interesting because males outnumbered females by 5 to 1 in the group expressing an intent to ride transit in the pretransit survey.
5. 29 percent were black, 58 percent were white, and 14 percent were others.
6. Most of the ridership was during the morning peak.

SUMMARY AND CONCLUSIONS

Previous research examining some methods for predicting behavior with questionnaires has been reviewed and a conceptual framework (Figure 1) outlining the various types of factors that have been used to assess behavioral intent has been described. Such research indicates that the percentage expressing positive intentions to use transit must be divided by a number between 3 and 5 to mirror actual behavior. The results of two surveys have also been reported. The pretransit survey was conducted in 1983, just before the opening of Metrorail in Miami (Dade County). The posttransit survey was conducted in 1987.

Just before Metrorail opened in Miami, ridership projections for the system indicated that (depending on pricing assumptions) as many as 202,000 riders might use the system daily. A pretransit survey was undertaken on the UM main campus in April 1983 of administrators, faculty, staff, and students to discern the probability that each group would take Metrorail to campus. The overall conclusion from this study was that 5,800 persons expressed an intention to access campus using Metrorail at least "once a month or less." Applying a rule from the literature and survey information concerning projected frequency of use led to a prediction of 427 riders expected on a randomly selected weekday.

In 1987, an intercept survey (the posttransit survey) was conducted at the UM Metrorail station. All persons disembarking Metrorail and entering university property were counted as using Metrorail to access the campus. An attempt was made to interview each of these persons. Approximately 313 interviews were completed.

The results of the posttransit survey indicate that only about 350 persons were riding Metrorail to UM each day in 1987, quite close to the 427 passengers predicted by the model, particularly because respondents in 1983 were asked to assess the likelihood that they would ride a system with which no one was yet familiar. These results are encouraging for the continued use of behavioral intent questions in predicting transit ridership.

Clearly, in spite of advances in transportation modeling, transportation planners still do not have a series of models that make accurate predictions of travel demand and modal split. The results clearly argue for further research into the use of behavioral intention questions in modal choice modeling.

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Transit-Sensitive Suburban Land Use Design: Results of a Competition

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The International City Design Competition (ICDC) is analyzed to determine the extent to which public transit was included by planners, architects, and engineers in their visions of the future for suburban areas. The ICDC provided an opportunity for experts in urban design to present concepts for the form of cities in the year 2020. The ICDC generated over 250 entries from over 40 countries. An analysis of the suburban portion of the ICDC is described to determine how (or if) public transit was considered and to partially identify that state of the practice of land use design as it relates to transit. Results of the analysis indicated that, in general, entrants favored a town center, with neighborhood or crossroads approach in their designs of the suburban area with limited use of corridor development patterns. Increased open space and a mixture of housing types were also frequently used. However, the analysis showed a limited use of public transit as a factor in suburban planning. Only 43 percent of the proposals evaluated explicitly used public transit and only 12 percent of the proposals evaluated were judged to have used it appropriately. Bus transit, park and ride services, or commuter rail were seldom considered as an option for suburban areas. Further analysis of planning handbooks or guides and accreditation criteria for educational programs related to land use planning showed little explicit consideration for public transit. These results imply that the state of the art for using public transit as a land use design consideration is poor and that, if this view holds, little change is expected in the automobile-dominated suburbs in the future.

There has been a rapid growth in the level and complexity of suburban activity during the past decades. Suburban areas that used to be thought of as bedroom communities for commuters into a central city have now become multifunctional areas with a full range of employment, business, and institutional activity, some of which rival downtown areas. A diverse set of activities covering all aspects of modern life have become available in suburban areas along with all of their associated problems. No longer are suburban streets quiet avenues. They have become crowded arterials with severe traffic congestion and safety problems. There is a critical need to develop means of public transport that can be used to relieve these problems as well as to provide better mobility for residents and workers in suburban areas.

Efforts to incorporate public transport into suburban activity centers have had limited success. Travel patterns are highly diverse, with trips from many origins to many destinations and few concentrated corridors of demand. Activity centers and trip generators are poorly tied to each other and scattered in many locations. Buildings are difficult to access by transit or by foot in an automobile-dominated world. Transit is not typically considered in land development, planning, and implementation decisions and it is difficult to retrofit transit into a suburban environment.

Most work on the problem of transit in suburban areas to date has concentrated on the development of new methods of operation or administration of public transit services in suburban areas. Demonstration projects have been attempted and new services have been offered with the hope of finding effective transit solutions to suburban travel problems. Although these efforts certainly have merit, they often ignore the underlying land use design issues that are the root of transportation problems. Land use decisions are made, site designs are approved, and projects are implemented with little or no regard for public transportation, on the assumption that the automobile is the only mode of transportation available. Little systematic work has been done to develop land use patterns that can be designed in response to transit needs. Work done in the United States [Seattle Metro, Snohomish County (*1,2*)] and in Canada [BC Transit (*3*)] provide limited guidance, but the real estate developer or local planner who wishes to design projects to facilitate transit use has little information available. The purpose will be to examine how urban designers and planners view the role of transit and transit-responsive land use and to point out future trends and directions in these areas.

The objective will be to investigate the state of the art of suburban land use planning to determine the extent to which public transportation is considered. This will be done by examination of the entries submitted in the International City Design Competition (ICDC) as well as a partial look at the basic literature in the form of planning textbooks and standards. The ICDC was an international urban design contest that provided an opportunity for design professionals to present their visions of how future cities should be designed. These entries provide a glimpse into the current thinking of professionals involved with land use design and decision making and can help to indicate how future land use planning will occur. Approaches used in the suburban design component of this competition, in nearly 200 entries from over 40 countries, are summarized. In addition, criteria were developed that can be used to assess whether a design is transit sensitive.

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CRITERIA FOR TRANSIT-SENSITIVE DESIGN

Transit can be successful in attracting usage away from the automobile if it provides a user-oriented service. User-oriented transit operates directly between passengers' origins and destinations without transfer, at a convenient schedule, and at a price that is competitive with the automobile. Transit stops should be easily accessible to building entrances to minimize walking and there should be clear pathways that connect activity points and transit services. Transit-sensitive land use, then, recognizes these factors and provides convenient connections between land uses and transit services. Furthermore, trip ends are concentrated in convenient locations to provide a sufficient market for transit services. In order to determine the extent to which the ICDC entries were sensitive to factors that lead to successful transit, a set of criteria were developed. These criteria related to concentrations of trip ends, pedestrian movement, and ease of operation of the transit service. They are as follows:

1. Density of Land Use. Are densities feasible for transit utilization?
2. Number of People. Is the total number of people who live or work sufficient within the market area of a transit stop or route (¼-mi radius)?
3. Concentrated Locations. Are the locations of housing, employment, commercial activity, etc., concentrated in relationship to potential transit lines?
4. Pedestrian Orientation. To what extent does the design consider pedestrian movement?
5. Minimize Walking. Does the design provide logical pathways that connect land uses with the location of potential transit services so that overall walking is minimized?
6. Through Routing. Does the location of streets permit easy movement of transit vehicles into and out of the area without backtracking or circuitous routing?
7. Turns Required. How many turns are required for transit vehicles to serve the area? Fewer turns are better.
8. Right-of-Way Available. Are rights-of-way (either streets or guideways) that can be used for transit services provided?
9. Overall Feasibility. An aggregate indicator, combining the other criteria into a single value.
10. Evidence of Transit. Is transit mentioned in the text or graphics accompanying the design or is transit service apparent from the presentation of information

Each design was systematically reviewed according to these criteria to assess the degree to which people considered transit in land use design. Over 200 projects in the competition were evaluated for a variety of transit and land use attributes of the suburban portion of the competition. Because of the wide range of the proposals, three pretest stages were required to develop an appropriate evaluation form. Two research assistants examined the suburban aspects of the proposals, noting project attributes on standard survey forms; the survey forms included multiple criteria to measure the characteristics of each proposal; interobserver reliability and sampling throughout the project were assessed by the principal investigators. Some 82 (31 percent) of the projects were eliminated from the survey because they did not address the suburban element of the competition, they presented highly abstract or incomplete solutions, or the submissions were unavailable for examination.

THE ICDC

Description

The ICDC was conducted by the School of Architecture and Urban Planning at the University of Wisconsin—Milwaukee to develop innovative ideas for cities of the future (*4*). This international competition, held in 1988–1989, provided $125,000 in prize money to winning proposals chosen by a renowned jury of planners and scholars. The competitors were "challenged to create innovative and credible visions for Milwaukee in the year 2020." In addition, these solutions were to be usable in similar settings throughout the world. Planners, architects, and designers put forth their concepts and visions of the city of the future addressing the urban center, an older neighborhood, and a relatively undeveloped suburban fringe area.

Milwaukee was chosen as the site of the competition because it is representative of many cities that experienced rapid economic development and growth tied to manufacturing during the past century. Such cities are currently going through profound changes in their economic structure as they move from a manufacturing to a service base. The competition's program directed entrants to develop "innovative proposals that responded to the social and economic forces of today."

The suburban element of the competition involved the design of a portion of the City of Oak Creek, south of the City of Milwaukee. An area of land approximately ¾ mi square, with an existing mixed land use of residential development, with large agricultural areas and open space, was used as the competition site. Approximately 70 percent of the land was in nonurban use. The area was chosen to represent suburban areas with potential for development. It is located near a major freeway corridor, has a freight rail line, as well as several arterial roadways passing through it, and is near Milwaukee's airport.

Competitors were asked to outline their vision of the area in terms of expected changes in land use, rate of development, relationship to the metropolitan area, size of projects, degree of replacement of existing development and preservation of the natural environment. This program for the future would then provide a basis for the physical layout of land uses and infrastructure for the area. Entries were submitted on standard-sized boards that contained a written and graphical presentation of the designs. The use of public transit was up to each of the competitors.

ICDC Evaluation Results

Characteristics of Entries

Over 250 entries were received from architects, planners, and engineers from 45 different countries. The United States contributed 81 participants; other North American countries had

22; Eastern Europe, 44; South America, 13; Asia/Pacific, 39; and other (Africa/Middle East) had 10 entrants. A number of submittals had several countries represented on the same team. The competitors represented a diverse group composed of professionals and students, academics, and practitioners, first-time competitors as well as winners of 30 other competitions. Typical team size was two to four members with 75 percent of the participants practicing professionals and 20 percent students. Architects were represented on 83 percent of the teams, urban planners on 42 percent, engineers on 8 percent, and landscape architects on 11 percent. Private firms contributed 38 percent of the entries, public agencies 11 percent, university faculty 27 percent, and students 39 percent. Competitors were urged to form interdisciplinary teams, and many of the higher-ranked solutions came from international teams composed of architects, engineers, planners, and artists. Overall, 3 teams won gold medals and shared a prize of $75,000, 4 silver medal teams shared $50,000, and 15 teams won honorable mentions. Collectively, the winning entries represented Argentina, Australia, Austria, Brazil, Canada, China, India, Japan, Poland, and the United States.

Suburban Design Approach

A total of 182 entries were analyzed to determine their approach to suburban land use design. These entries were those that planned for growth in the area and excluded ones that proposed removal of existing development or did not address the suburban portion of the competition. The general characteristics of the designs are shown in Figures 1–4.

Design Approach The overall approach used by entrants is shown in Figure 1. The most frequently used concept, seen

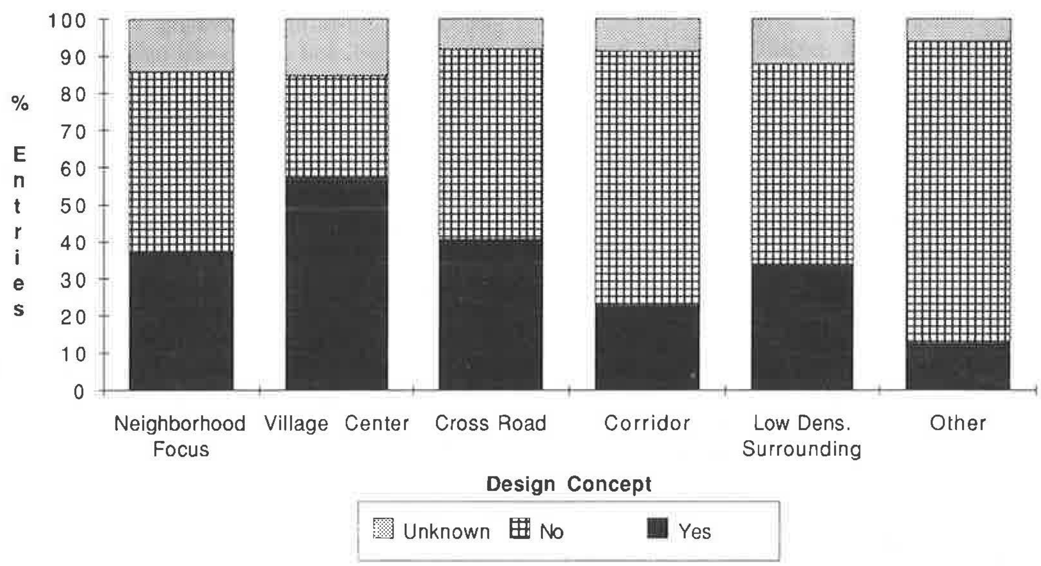

FIGURE 1 ICDC suburban entries—design approach.

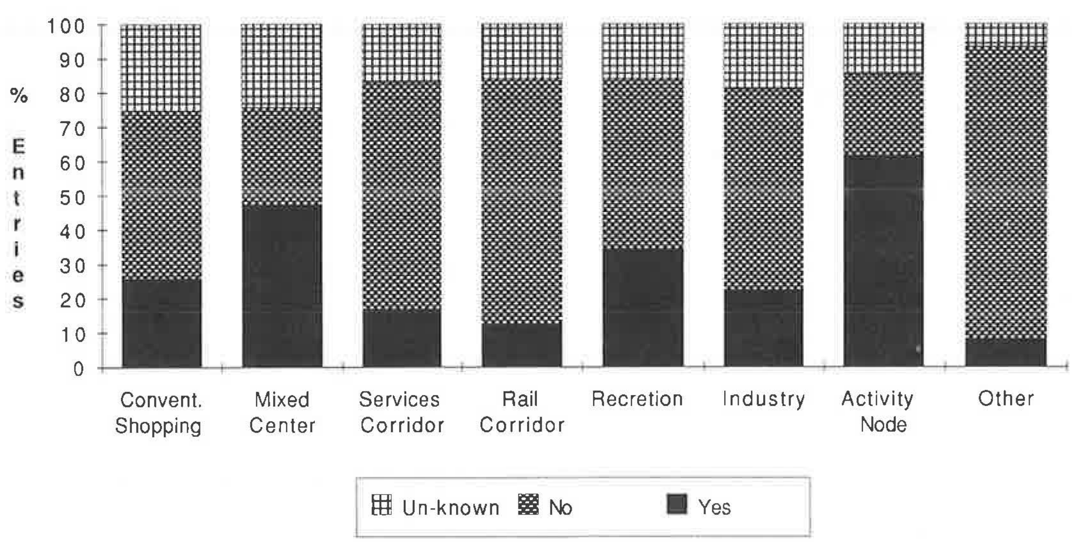

FIGURE 2 ICDC suburban entries—commercial development patterns.

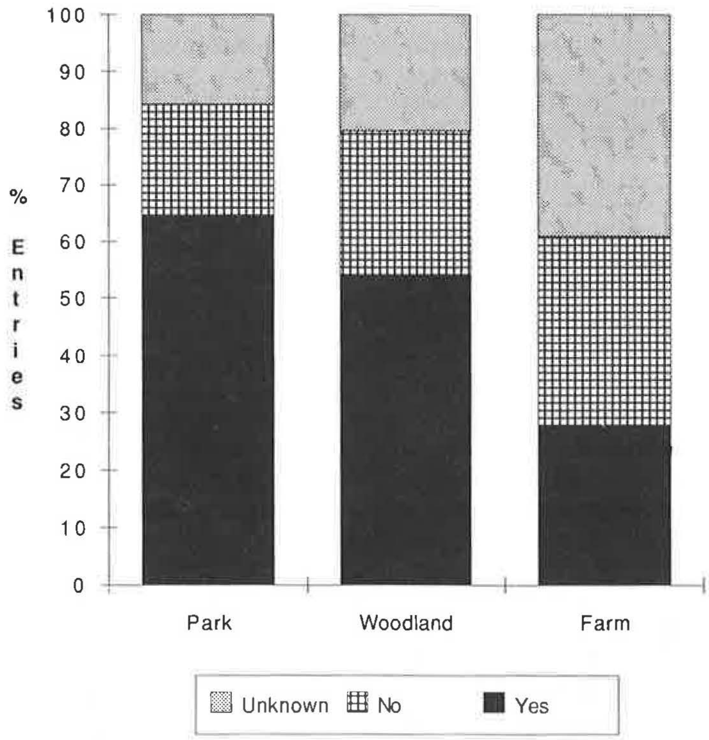

FIGURE 3 ICDC suburban entries—use of open space.

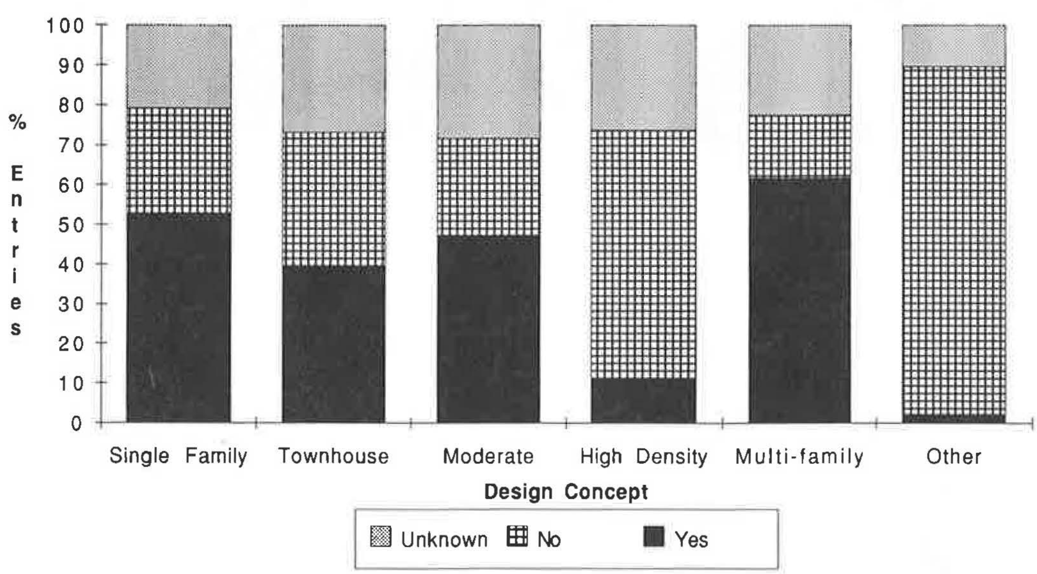

FIGURE 4 ICDC suburban entries—housing types.

in over half the submissions, was a village center approach. These designs attempted to create a town center with multiple activities. Similar concepts, to create several neighborhood focal points or to use a crossroads development pattern, was used by about 40 percent of the entries (some used multiple concepts). Development along transportation corridors was used by about 20 percent of the entries. Typically the designs would include mixed land uses with a central area for shopping and employment. Many proposals concentrated development on a portion of the site and left substantial open space.

Commercial Land Use Entrants also favored a centralized approach for commercial development (Figure 2), with 62 percent of the entries using a high-activity node and 49 percent using a nonconventional activity center, both mixed-use concepts at different levels of intensity. Entertainment and recreational concepts were used by 34 percent of the entrants, and conventional shopping center concepts were used by 26 percent. Development along corridors either as a strip commercial area or along the rail corridor was rare, with less than one-sixth of the entries using such an approach.

Open Space Entrants proposed extensive use of open space (Figure 3) with nearly two-thirds of the entrants proposing to increase the area of parks and greenbelts and half including increased woodland areas. Permanent agricultural use was proposed by about one-fourth of the entries.

Housing Types A mixture of housing types was used by the entrants (Figure 4). Generally, entrants favored higher densities that are typical in American suburbs. Multifamily housing was included in 62 percent of the designs, single family housing in 53 percent, moderate density housing in 47 percent, and townhouses in 40 percent. Housing in the form of high-rise buildings was, however, relatively rare, appearing in about 11 percent of the designs.

Transportation Component Expansion of the street system was the most frequently used transportation-related change (Figure 5), with 77 percent of the entrants proposing it. Increased pedestrian circulation was proposed by 45 percent of the entrants, while an increase of parking was proposed by 40 percent. Increases in transit or new transit links were proposed by about one-third of the entrants.

Mass Transit The major portion of the analysis was concerned with whether transit was used and the quality of its use in the proposals. These results were disappointing for those who hope that the credible visions of design professionals in the future will include public transportation. The majority of entrants (57 percent) did not mention public transit either in the text or the graphics of their presentation. Of those that did include transit in their submissions, by far the most popular mode of transportation was light rail (Figure 6), which was included in 31 percent of the entries. Bus, perhaps the most likely mode for suburban areas, was mentioned by only 8 percent of the entrants, whereas park and

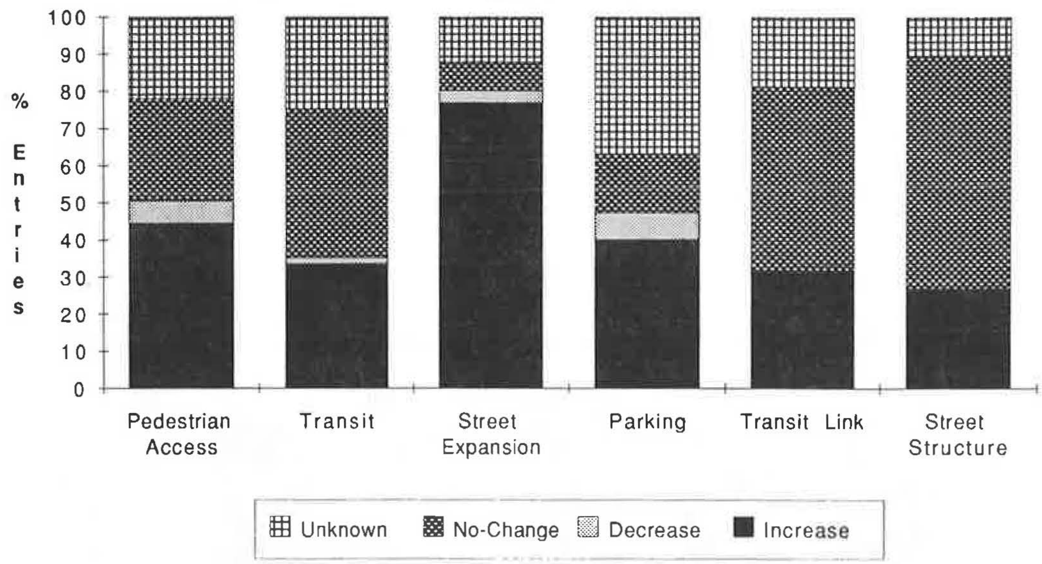

FIGURE 5 ICDC suburban entries—transportation-related changes.

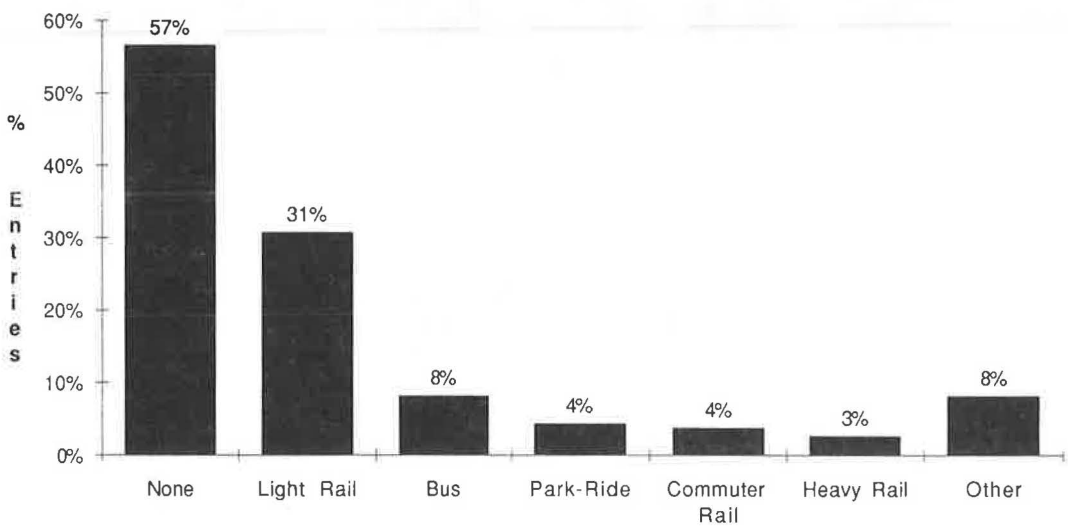

FIGURE 6 ICDC—transit modes used by entries.

ride was mentioned by only 4 percent. Other modes of transit were used by less than 10 percent of the entrants. In summary, few proposals included transit as an element of their design, and those who did include transit used light rail as the preferred mode. Use of bus, park and ride, and commuter rail—the most commonly used modes of travel in the suburbs—seldom entered the vision of the future in the minds of the design teams.

Land Use/Transit Sensitivity The planning criteria discussed earlier were developed to determine if the entries were sensitive to factors that could lead to successful transit services. These criteria were related to the categories of population concentrations at trip ends, pedestrian movement, and ease of transit operation. Each entrant was assessed on these criteria on a 0 to 5 scale and an overall rating was developed as shown in Figure 7. Approximately 25 percent of the entrants proposed designs that had land use patterns that were judged as having a "good" sensitivity to transit, with a rating of 4 or 5; about 50 percent were judged "fair," with a rating of 3; and about 25 percent were judged as "poor," with a rating of 1 or 2. Those entries that explicitly mentioned transit were rated only marginally better in providing design attributes conducive to transit success than those that did not include transit. Only 12 percent of all entrants both used transit and submitted designs that were evaluated as satisfactory in their sensitivity to transit as a land use design factor.

With respect to the various criteria for transit (Figure 8), entrants who mentioned transit did best at providing sufficient rights-of-way (73 percent judged as good) and poorest at minimizing walking distance (28 percent judged as good). Results were similar for those who did not mention transit; 63 percent did a satisfactory job of providing rights-of-way and only 18 percent provided short walking distances to potential transit routes. In general, those who did not mention transit did poorer on pedestrian and transit operational criteria, but better in criteria related to concentrations of trip ends than those who did mention transit.

A comparison of the origins of participants versus their sensitivity to transit is shown in Figure 9. Entrants from the United States and North America designed land use for transit marginally better than entrants from elsewhere in the world. Interestingly, entrants from countries that already have extensive transit systems (eastern Europe and Asia/Pacific areas) used public transit concepts less frequently than entrants from other areas such as North America.

EXISTING GUIDANCE FOR TRANSIT-SENSITIVE DESIGN

The results of this analysis led to the examination of the extent to which public transit, as a land use design consideration, is mentioned in standard textbooks and guides often used by practicing planners or developers. Accordingly, a cross section of this material as well as the accreditation criteria for planning architecture and engineering programs were examined to determine what the state of the practice is in transit sensitive land use design. The state of the practice differs from

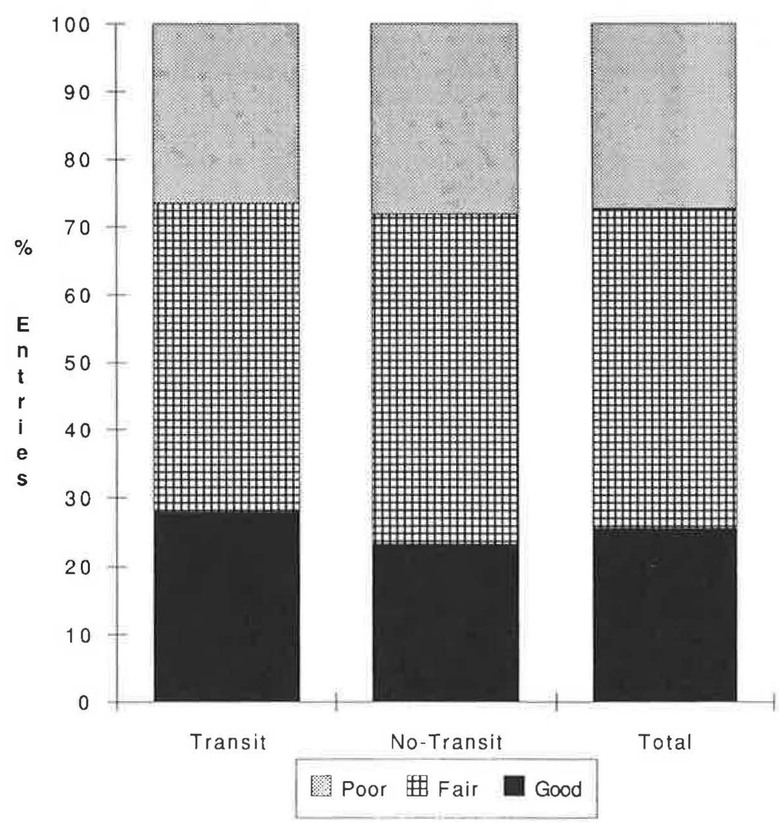

FIGURE 7 ICDC suburban entries—land use/transit sensitivity.

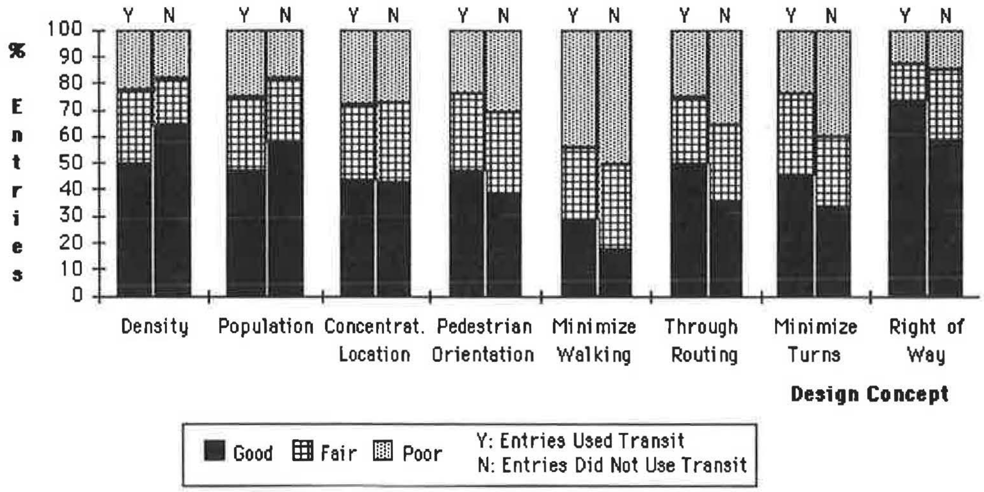

FIGURE 8 ICDC suburban entries—transit evaluation.

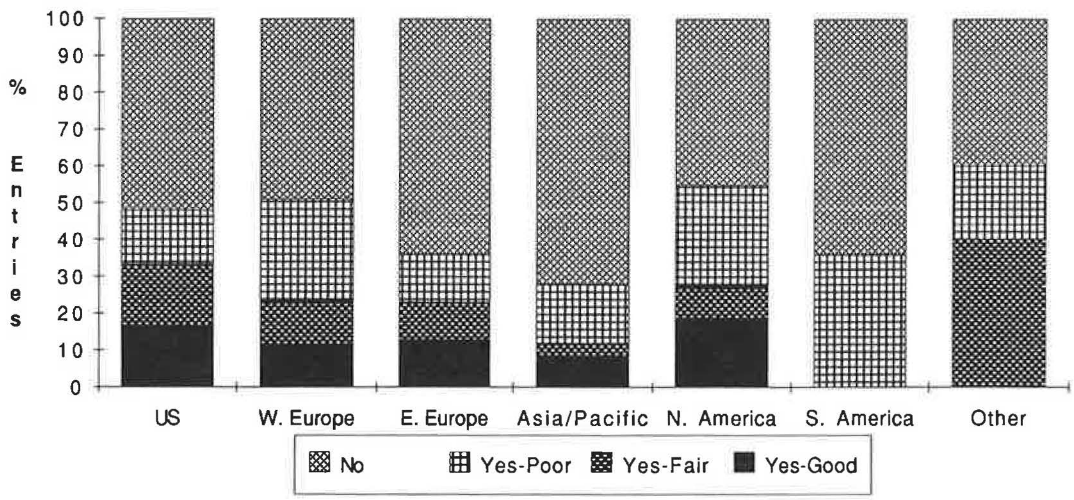

FIGURE 9 ICDC suburban entries by geographical area and transit-sensitive land use.

the state of the art in that materials examined were widely available rather than found only in limited circulation journals or technical reports.

Handbooks and Design Guides

A review was made of a number of the standard textbooks and design guides used by planners and developers to provide information on project design. This review included material available to real estate developers, architects, and planners through professionals organizations as well as in the form of textbooks or handbooks. The purpose of the review was to determine what information, if any, was available to design for transit service and to find out how prominent the issue of transit service land use design is, especially in suburban areas.

The results of this review (*5–12*) were disappointing. Public transit service in the suburbs is seldom, if ever, mentioned in planning texts and handbooks as a consideration or concern in the material reviewed. Generally, guidelines for land use design in the suburbs assume that only automobile transportation is available. Little information is provided about public transit; in many cases it is not mentioned or, if it is mentioned, it is in a historical context. These materials are strong in their coverage of land use but weak in the role of public transit.

Textbooks and handbooks in transportation and traffic engineering (*13–17*) contain substantial materials on transit. Examples of such information include turning radii, stopping zones, and special design to accommodate high-occupancy vehicles on streets and highways; however, little mention is made of land use design and considerations in planning that would affect the success of public transit. These materials are stronger in their coverage of transit, but weak in land use. There seems to be two different worlds—a world of land developers, architects, and planners who seldom think of transit, and a world of transit and traffic professionals who seldom deal with broad land use issues. Although it is not possible to consult all standard sources, nor to know in fact what factors people consider in their design work, a review of the basic written body of work commonly available indicates that the typical practitioners involved in this field have few resources available that would guide them to a strong consideration of land use planning sensitive to public transit concerns.

Accreditation Criteria

A review was also made of the criteria used to accredit educational programs in architecture, planning, and engineering. Here again, little if any mention is made of public transit. For instance, the latest criteria for the accreditation of architectural schools containing some 77 specific areas of study, including detail within each area, does not mention transportation nor are any transportation-related subjects present. The criteria for schools and departments of planning in the United States is similar. No mention is made of the need to cover transportation topics. The results of this competition are consistent with the curricula. Public transit is not an issue when it comes to defining the basic body of knowledge needed to perform in these fields.

CONCLUSIONS AND IMPLICATIONS

In terms of the use of transit in future suburban planning, the results were disappointing. About two-fifths (43 percent) of the proposals evaluated explicitly used mass transit as an element of suburban land use design; only 12 percent of the competitors included mass transportation and had a land use design that used transit appropriately. In the credible visions of most of the entrants, it appears that the automobile will continue to be the dominant form of future transportation in suburban areas. Entries from U.S. professionals were comparable to foreign entries in their ability to use transit. An additional review of commonly used handbooks and guidelines and accreditation criteria for academic programs in architecture, planning, and engineering showed little, if any, concern for public transit as a land use design consideration.

The entries to the ICDC are a selected sample of planners and architects, and the sample does not represent a careful sample of these professions. However, the goal of the competition in encouraging visions of the future and the makeup of the competitors would suggest a progressive outlook. Furthermore, the design competition was free of many constraints that could limit creativity in design. In view of this, the analysis of the projects was particularly frustrating in terms of the competitor's perception of the role of transit. Not only did relatively few competitors use mass transit in their designs, but a good portion of those that included transit did not use it appropriately.

The consequences of this analysis are disturbing. Public transit does not seem to be a strong part of the vision of the future by those who will make many of the design decisions for the suburbs. Furthermore, it is not strongly considered in the basic resources, written or educational, that provide the fundamental body of information that these professionals use. In a future with finite resources, an automobile-dominated world is assumed. Planning decisions are made with little thought of the potential role for other modes, especially transit or walking. Unless such trends are changed, serious problems will arise in the future in attempting to adapt and retrofit our suburban communities to changes in future resource availability. In order to provide a future in which transit plays a role, those involved in transit must make the others, who are largely responsible for land use design, aware of the benefits of transit and create a vision of the future that includes a broad set of transportation alternatives.

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The I System: A Campus and Community Bus System for the University of Illinois at Champaign-Urbana

JOSEPH A. MORIARTY, ROBERT PATTON, AND WILLIAM VOLK

The planning and results of an innovative mobility and transportation program for the University of Illinois at Urbana-Champaign, called the "I System," are summarized. The I System integrates a new system of circulating campus bus routes with the existing regular routes of the local transit district. Both the campus and community routes are operated by the Champaign-Urbana Mass Transit District (CUMTD). The I System is jointly funded by a mandatory student transportation fee, the University of Illinois Parking Division, and State of Illinois transit operating assistance. The primary component of the I System is that a valid student identification card becomes an unlimited access bus pass for both the system of new campus routes and the regular community-wide bus routes. This integrated system helps to combat congestion and parking problems by intercepting off-campus trips at the point of origin and providing access to dispersed university activity centers, in turn reducing the need for an automobile both for commuter trips to campus and intracampus trips. The results of the I System have been impressive; ridership for the CUMTD has approximately doubled to 5.4 million passenger trips per year. Because of the success of the I System and complementary Transportation System Management measures, demand for campus parking has been reduced by 1,000 spaces. Consequently, $5 million worth of new parking garage construction has been postponed. The I System is effective because of the unique partnership that was forged between the students, the university administration, and the CUMTD, which maximized the use of existing transportation resources.

The planning and results of the first year of operation of an innovative mobility program for the University of Illinois (U of I) campus, that integrates a new system of circulating campus bus routes with the existing regular community routes of the Champaign-Urbana Mass Transit District (CUMTD) are described. The primary component of this integrated system, called the "I System," is that a valid U of I student identification card becomes an unlimited access bus pass both for the new campus routes and the regular community bus system. A small $10 fee for each semester is assessed on all students to fund the cost of additional service. The I System responds to unique congestion and mobility problems by intercepting off-campus trips with the regular community system, and enhances mobility on campus by providing access to dispersed university activity centers through the system of new campus routes.

The results of the recently implemented campus-community I System demonstrate that transit can play a pivotal role in improving campus mobility in a cost-effective manner. The I System is effective because of the partnership between the university and the local transit district, which maximizes the use of existing transportation resources. Ridership for the entire CUMTD system, campus routes, and community-wide routes has approximately doubled to over 5.4 million unlinked passengers per year. The CUMTD operating cost recovery ratio has increased to 33 percent. Because of the success of the I System and complementary transportation systems management (TSM) measures, the university has reduced the demand for parking by over 1,000 spaces, postponing the need to construct $5 million worth of new parking.

The establishment of a comprehensive campus-community bus system took over 5 years with three student-wide referendums, a major change in transportation parking policy, and the active financial participation of the university administration. For students, faculty, and staff members, the new I System provides a cost-effective transportation alternative for commuting to campus and provides access to an increasingly expanding and disjointed campus.

THE COMMUNITY AND CAMPUS CONTEXT

The Champaign-Urbana Mass Transit District (CUMTD) is a special-purpose district providing transit services to the cities of Champaign and Urbana, Illinois, and to the U of I. The CUMTD has an active fleet of 50 buses, operating 10 weekday and Saturday routes, and 5 evening and Sunday routes. The annual operating budget is approximately $6 million. The CUMTD was created by a popular community referendum in 1971 following the termination of the privately owned bus service.

Champaign and Urbana are twin cities that are located approximately 100 mi south of Chicago in east-central Illinois. The urbanized area encompasses approximately 35 mi^2. The U of I main campus area is located midway between Champaign and Urbana (see Figure 1). The major trip generators are the university, downtown Champaign, downtown Urbana, Market Place Mall, County Fair Shopping Center, and Sunnycrest Mall.

The Champaign-Urbana urbanized area has a population of approximately 100,000 and on a per capita basis is the 11th densest urban area in the country, following San Francisco, California (*1*).

The U of I campus is approximately 700 acres in area, with 180 major buildings. The campus area accommodates the Uni-

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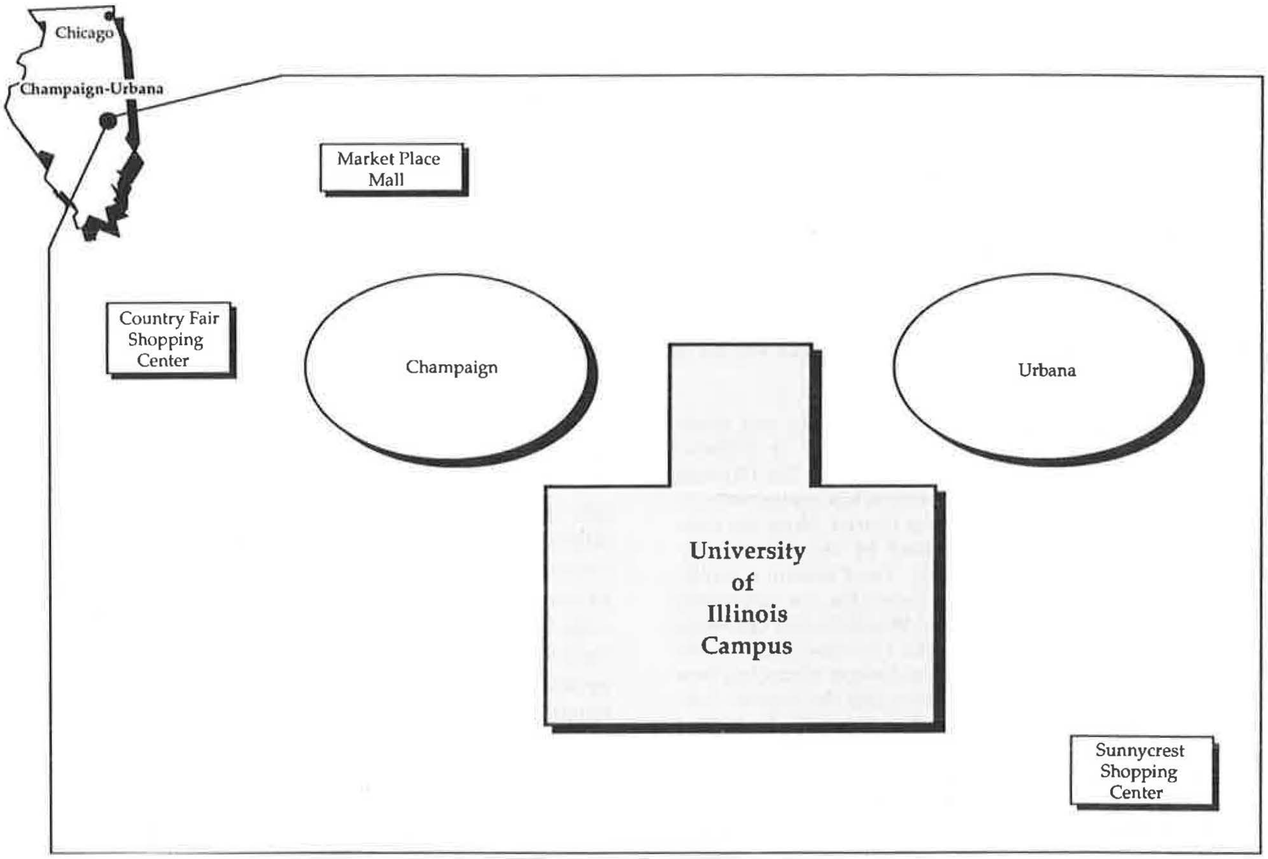


FIGURE 1 Champaign-Urbana locational map and primary traffic generators.

versity's 36,000 students and over 10,000 faculty and staff members. The U of I is the single largest employer in the urbanized area. Of the 36,000 students enrolled at the university, only 10,000 live in university residence halls. Of the remaining 26,000 students who live off-campus, the majority reside within a 1-mi radius of the campus (*2*). In terms of employment, economic activity, and population, the U of I campus serves as the de facto central business district of the urbanized area.

The CUMTD has taken advantage of this centralized activity and has oriented 9 of its 10 routes to the campus. The CUMTD system can be characterized as a modified timed-pulse system operating 7 days per week on 30-min headways during the base, and more frequently during the peak periods. From radiating points throughout the service district, the terminal points in downtown Champaign and Urbana function as major transfer centers for routes that converge at the campus via the densely populated student residential areas (see Figure 2).

Before the fall of 1989, average weekday ridership was approximately 10,000 unlinked passengers per day. Between 1984 and 1989, annual ridership has been in the general range of 3 million unlinked passengers per year (*3*) (see Figure 3).

The role of the university as a major centralized point of origin and destination for work and school trips was confirmed by a system-wide evaluation survey conducted in the spring of 1989. Results indicated a total of 34 percent of all surveyed weekday transit trip purposes were oriented to the University of Illinois campus, with 19 percent of these trips taken for university work purposes and 15 percent for university school purposes (*4*, p. 6). Table 1 presents a summary of service and user characteristics of the CUMTD regular route system.

The CUMTD was, and continues to be, successful at providing transit to and from the campus, but until recently had only limited success providing intracampus transportation. The most notable exception was the Orchard Downs route, which provided service to married student housing and undergraduate dormitories on the southern periphery of campus. Service modifications and fare adjustments had only marginal impact on increasing ridership. The management staff felt that 3 million passengers per year was the plateau of ridership for traditional transit trips for the district.

CAMPUS MOBILITY PROBLEMS

Until recently, the U of I campus was compact and self-contained, making walking and bicycling the mode of choice for intracampus travel. However, recent development patterns have changed the compact structure of the campus. This has played a significant role in contributing to the mobility problem on campus. New development, including academic buildings and residential units, has occurred in a dispersed and uncoordinated manner. The majority of these diffuse activity centers are located on the southern perimeter of campus up to 1 mi distant from the central campus area.

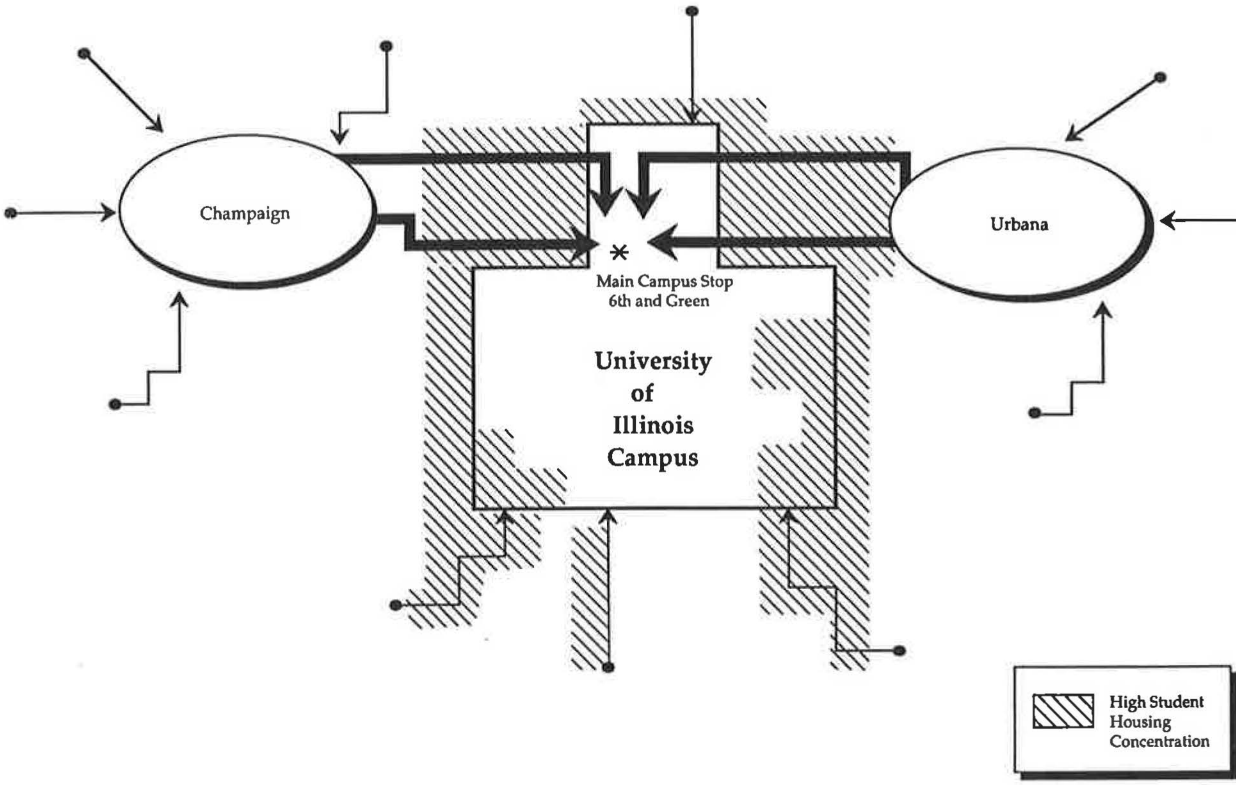


FIGURE 2 Conceptual illustration of route structure for CUMTD.

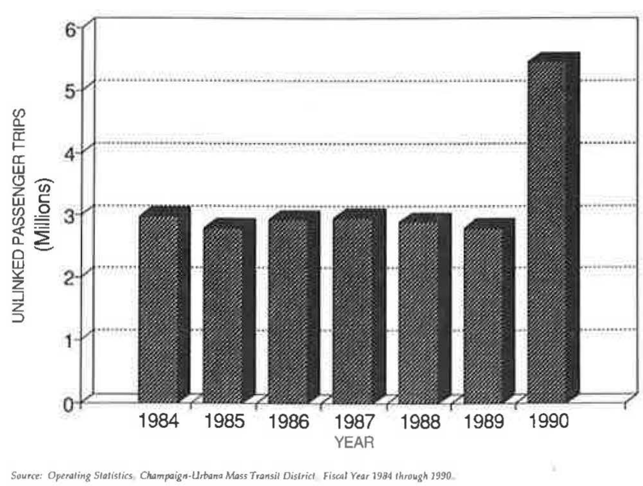


FIGURE 3 Ridership in CUMTD.

Because of these dispersed land use patterns, students, faculty, and staff grew more dependent on the private automobile to access these activity centers. The combination of high population density around the central campus area and the growing student dependence on the private automobile has created unique automobile congestion problems that are usually associated with larger urbanized areas. Intersections adjacent to the university are characterized by failing levels of service with severe vehicular, bicycle, and pedestrian conflicts. This is especially evident at class interchange times, as well as during the traditional peak traffic periods. Over half of Champaign-Urbana area, critical accident intersections are located on or near the U of I campus (*5*).

These campus congestion problems were exacerbated by the low cost of parking on campus that encouraged many students to drive to class and other university activities. For students that registered their cars with the university, there were a limited number of parking meters on campus for as low as 25 cents per hour. Student attitudes that were formed in suburban and rural areas also contributed to the congestion problem. It is possible that many believed they had a right to drive and expected that a place to park would be naturally provided.

Another factor that contributed to campus congestion was the university policy of providing reserved low-cost parking for faculty and staff on campus as close to the work destination as possible. At $78 per year, the U of I had one of the lowest parking rates in the Big Ten, a rate unchanged for over 10 years. These reserved parking spaces were allocated on a seniority basis. However, as the university has developed over the last 20 years, the supply of these reserved parking spaces had not kept pace with the demand.

In 1989, 650 new faculty and staff members were placed on a waiting list for reserved parking spaces. According to the Division of Parking, new faculty or staff members could wait up to 3 years to secure a reserved parking space (*6*). Consequently, for the interim, new faculty and staff members who wished to drive to campus were forced to park in remote stadium parking lots that were up to 1 mi away from the central campus. In order to provide access to these remote

TABLE 1 SUMMARY OF SERVICE CHARACTERISTICS BEFORE THE I SYSTEM

Demographics*		
• Population in service area:	94,245	
• Population density:	3,903 persons per square mile	
• Average distance to service:	95% of residents in district are within 1/4 mile of a bus stop	
Service Characteristics**		
• Number of routes:	10 Weekday/Saturday, 5 Evening/Sunday	
• Average headways:	30 minutes more frequent during peak periods	
Revenue and Subsidy**		
• Fares:	$.50 per trip	
• Passenger Revenue per Revenue Vehicle Hour:	$9.00	
• Operating cost recovery ratio:	25%	
Funding	Capital	Operating
Federal	80%	17%
State	20%	40%
Local	0%	18%
Ridership**		
• Average passengers per weekday:	10,000	
• Average Annual passengers:	2.7 million unlinked passenger trips	
• Trip purpose:***	- Work Trip to U of I:	19%
	- School Trip to U of I:	15%
	- Total U of I:	34%
	- Other Work Trip:	21%
	- Shopping:	8%
	- Parkland College:	5%
	- Social\Recreational:	4%
	- High School Trip:	7%
	- Junior High School Trip:	2%
	- Other:	13%
	- No response:	6%

* U.S. Bureau of the Census. Population and Land Area for the United States and Puerto Rico: 1980-1970, PC 80-S1-14.
** Operating Statistics. Champaign-Urban Mass Transit Transit District. Fiscal Year 1984 through 1990.
*** Barton-Aschman Associates, Inc. CU-MTD Strategic Planning and Performance Audit Study, August 1989.

lots, the university operated its own remote-parking shuttle bus system. This remote shuttle system was underutilized because of low service frequencies and long trip time.

Therefore, the mobility problem on the U of I campus consists of two interrelated components. The first is the problem associated with getting to and from campus, and the second is that once on campus, there is a general lack of accessibility to dispersed campus activity centers, especially for those without reserved parking privileges. As the university has grown, these factors have combined to create increasing conflict between vehicles and pedestrians, leading to a general deterioration in the transportation environment on campus for students, faculty, and staff members.

CAMPUS EXPANSION PROGRAM

During the mid-1980s, the university planned to implement a 10-year $250 million campus expansion and building program. The development program called for over 20 new buildings on campus. Eight new buildings are currently being built or have been recently completed. The campus would have three distinct campus quadrangles: north, central, and south. Because the university is essentially land locked in the north and central areas of campus, most of the proposed buildings would be erected on existing surface parking lots. Consequently, the majority of parking on the north and central areas of campus would have to be replaced with expensive parking garages, or displaced to remote stadium parking lots on the extreme southern edge of campus well over 1 mi from the central campus. Three proposed parking garages that would help relieve the parking problem were slated to be built after the completion of the new academic building.

The U of I Parking Division has estimated that through the combination of new demand, loss of additional parking, and shortages from previous years, 1,391 spaces would be required by 1996 to meet reserved parking demand for faculty and staff members. These estimates did not address the growing parking demand generated by graduate teaching assistants, research assistants, and other students on campus (*6*).

SERVICE CONCEPT

In April 1985, the Board of Trustees of the CUMTD adopted as one of its goals to "increase the District's share of local transportation in established areas and pursue new opportunities for public transportation." An ongoing objective was to "establish programs to more effectively increase ridership to and from the University of Illinois campus." Both the Board and management staff felt that the CUMTD could play a pivotal role in providing a cost-effective solution to the growing campus parking, traffic, and mobility problem.

Preliminary research was conducted to investigate how other university communities dealt with similar mobility problems. A survey of Big Ten universities and other major universities that provided campus bus service was conducted (see Table 2). The results of the survey indicated highest ridership among the universities that did not charge a fare but recovered the cost of providing the service through a mandatory student transportation fee, or through the university general fund. The most noteworthy examples included the University of Minnesota, University of Michigan, University of Iowa, University of Georgia, and University of Massachusetts (*7*).

A service concept emerged from this research that included the following components:

- A comprehensive service that would integrate the existing community-wide service with new circulating intracampus routes.
- Unlimited access to a free service. A student, faculty, or staff member ID would become an unlimited bus pass for the new campus routes and the regular 10-route community system.
- Short high-frequency campus routes, especially before and after the class interchange.
- Service to remote parking lots.
- Extended late night service.
- A low-cost mandatory transportation fee would be assessed for all students, faculty, and staff to fund this system.

Because over 70 percent of students lived off campus, it was felt that a system that would integrate the regular CUMTD community routes with a new system of campus routes would comprehensively respond to the dual transportation needs of the university community. An integrated campus and community system would intercept campus-destined trips at the point of origin, thus avoiding a potential automobile commute altogether. In addition, high-frequency circulating intracampus routes would reduce the need to depend on a car to access dispersed university activity centers and provide increased

TABLE 2 CAMPUS BUS SERVICES

School	Fleet Size	Type of Service	Funding	Fares	Recovery of Operating Costs	Ridership FY 1985
University of Minnesota	31	Campus/ Community	University General Funds	Free On-Campus 75¢ Off-Campus	88% University 12% Farebox	4,169,274
University of Michigan	35	Campus Only	University General Funds	Free Fare	100% University Funded	3,600,000
Ohio State University	13	Campus Only	University General Funds(1)	Free Fare	100% University Funded(1)	3,500,000
University of Iowa	17	Campus Only	Mandatory Student Transportation Fee Other(2)	Free Fare	58% Transportation Fee 15% Parking Revenue 27% Other(2)	3,350,000
Indiana University	17	Campus Only	Fares and Passes	40¢ Fare $49.50/Semester	98% Farebox 2% Other(3)	2,242,967
University of Georgia	29	Campus Only	Mandatory Student Transportation Fee	Free Fare	100% Transportation Fee	12,500,000
University of Massachusetts	36	Campus/ Community	University General Funds	Free Fare	35% State 25% Federal 25.6% Parking Fees Other(4)	3,600,000

Notes:

(1) Night Service Funded by Residence hall fee.
(2) Other includes: 12.5% State, 7.5% UMTA, and 7% University General Fund.
(3) Other includes: 2% Advertising.
(4) Other includes: 9.6% Student Fees and 4.8% University Funds.

Survey conducted by the Planning Department of the Champaign-Urban Mass Transit District, 1985 - 1986.

mobility for students without access to an automobile. For automobile commuters who are forced to park in remote parking lots, a high-frequency circulating bus route would provide a low-cost alternative to access the central campus area from the remote lots.

Another important component that favored the CUMTD as the logical campus transportation provider was that the CUMTD had access to state of Illinois transit operating assistance. Because of this state transit operating assistance, the CUMTD could reduce the total cost of providing the service to the campus community. As the established transit provider in the community, the CUMTD also had the necessary equipment, maintenance facilities, labor, training capability, and overall management resources to easily expand service. The existing CUMTD services and infrastructure offered economies of scales that the university could not replicate in a cost-effective manner. Furthermore, a campus bus service concept was also included in the new campus development plan as a potential strategy to reduce automobile congestion and to preserve green spaces on campus.

At the time when the campus-community bus service concept was being formed, the CUMTD was invited to participate on a university-sponsored Campus Parking and Transportation Committee. This committee was established to address the mobility problems on campus. Contrary to the recommendations of the CUMTD, the Campus Parking and Transportation Committee focused on parking as the answer for the campus transportation problem. The CUMTD felt that a parking-only solution would ignore the mobility needs of the students, clearly the largest campus population segment contributing to and affected by the deteriorating transportation conditions on campus. In addition, the CUMTD felt that a parking-only solution would create more vehicular congestion rather than reducing it. The CUMTD also approached the chancellor and other university administration officials. The university administration was interested in the campus-community bus service concept, but was unwilling to mandate a student transportation fee to help fund the system. However, the university administration would collect a transportation fee if the students voted for it.

STUDENT REFERENDA

Because students were largely ignored by the Campus Parking and Transportation Committee, but represented the largest

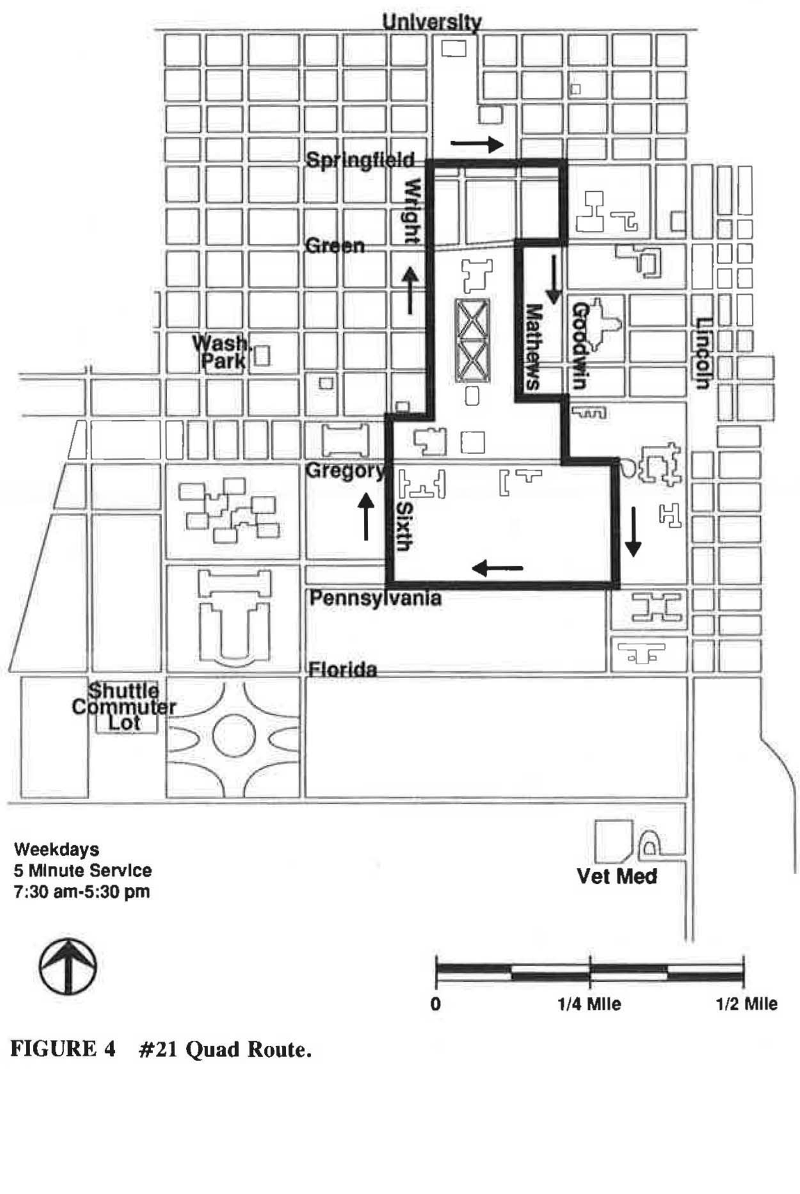


FIGURE 4 #21 Quad Route.

group that would benefit from a campus-community bus service, the CUMTD directly approached the Student Government Association to place this concept on a campus-wide student referendum in December 1987.

Working with a committee of student representatives, the campus-community transportation system plan evolved into the following components:

- Quad circulator, 3- to 5-min service frequency (new route);
- East-west circulator, 15- to 30-min frequency (new route);
- Extended late-night service (until 2:00 a.m. on weekends); and
- Unlimited access to existing CUMTD 10-route network.

A valid student ID would become a bus pass for the new campus routes, as well as for the regular community system, and a $15 per semester mandatory fee would be assessed on all students to fund the cost of the system over 3 years.

However, this referendum failed by 500 votes with over 9,000 votes cast. The primary opposition to the plan revolved around the $15 nonrefundable mandatory fee and the 3-year trial period. Even though the referendum was defeated, there were some significant positive repercussions: record voter turnout, campus-wide focus on the deteriorating aspect of mobility on campus, and heightened awareness on the part of the university administration that this concept was worth pursuing as a cost-effective means to help solve the transportation problem on campus.

After a change in the university administration, the campus-community bus service plan was resurrected for another student-wide referendum in April 1989. At the same time, major building components of the campus expansion program were being initiated. The university administration was beginning to realize the costs associated with replacing reserved surface lots with parking garages in the central campus area. Three 500-space parking structures were planned to replace the surface parking lots taken for the campus expansion program. The cost of constructing parking garages was estimated at $11,000 per space.

An important fact that the university had to consider was state legislation mandating that the Parking Division be a self-supported unit on campus, which means the costs of oper-

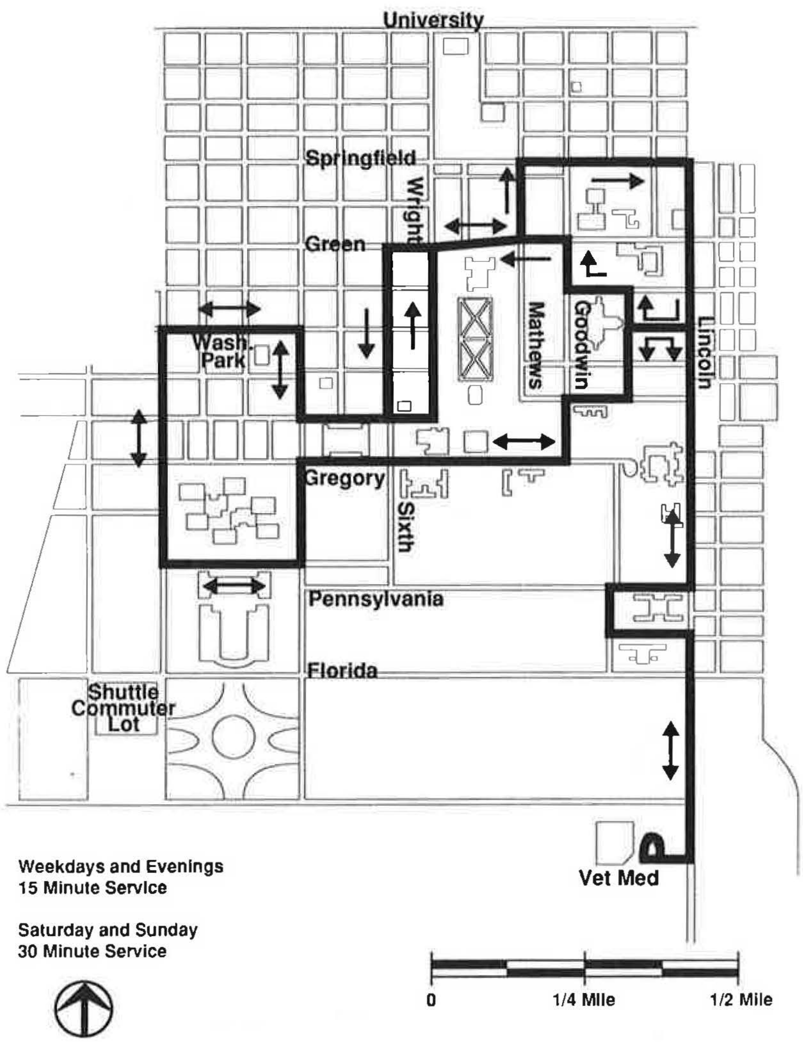


FIGURE 5 #22 Illini Route.

ating, maintaining, and building parking were to be borne entirely by fees collected from university parkers. The previous fee structure only covered the operation and maintenance of the existing surface lot system. No surplus parking revenue was generated to help fund new parking garage construction.

Consequently, by 1996 reserved parking rates on campus would have to be significantly increased to $250 annually to cover the costs of building these new garages (*6*). Clearly, the university was looking for a more cost-effective solution to the parking and transportation problem on campus. After further consideration, the university agreed to be an active participant in the comprehensive CUMTD campus-community transportation plan.

Through the Parking Division, the university agreed to provide $180,000 of the $880,000 needed to operate the system, so that the mandatory student fee could be lowered to only $10 per semester. The university also intended to implement a range of complementary TSM strategies to help provide incentives to reduce the demand for faculty and staff reserve parking (*8*). The TSM strategies included the following:

1. Reduced-rate mass transit district bus pass for $30 per year for faculty and staff members, an 80 percent reduction of the regular price of $150 per year. The university agreed to a $120 subsidy for an annual bus pass for faculty and staff parkers willing to forfeit all parking, rental, and waiting list privileges.
2. Carpool and ride share permits for $30 per year. Each carpool must consist of at least three full-time faculty or staff members. Only a primary renter is issued a parking space; all other members of the carpool forfeit parking, rental, and waiting list privileges.
3. Remote parking lot with shuttle service for $30 per year. University-provided shuttle service to remote lots that are on the southern periphery of campus.
4. Increase all reserved space parking to $102 annually effective July 1, 1989, to $126 by July 1990 with escalating annual increases after 1990.

With the active financial support of the university administration, the campus-community bus service concept was again put to a student vote. The critical changes since the first referendum were a reduced $10 per semester mandatory fee and a 1-year trial period.

The April 1989 campus-community bus service referendum

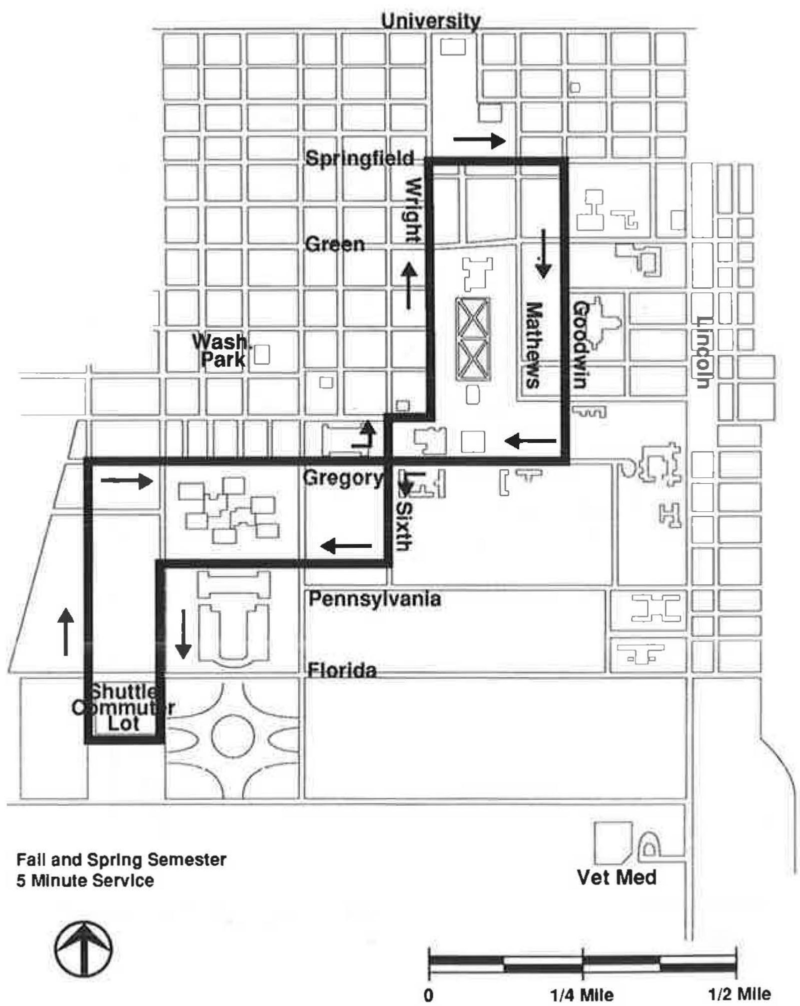


FIGURE 6 #23 Shuttle Route.

was successful with 3,102 students voting for the campus-community bus service out of 4,800 votes cast.

RESULTS

The new campus-community bus service, the I System, was implemented in August 1989 and included the following components:

- #21 Quad Route, weekdays 7:30 a.m. through 5:30 p.m., 5-min service (Figure 4);
- #22 Illini Route (Figure 5);
  - –Weekday 7:00 a.m. through 2:00 a.m., 15-min service;
  - –Saturday 12 noon through 6:00 p.m., 30-min service;
  - –Saturday evening 6:00 p.m. through 2:00 a.m., 15-min service;
  - –Sunday 12 noon through 6:00 p.m., 30 min service;
  - –Sunday evening 6:00 p.m. through midnight, 15-min service;
- #23 Shuttle, weekdays 7:30 a.m. through 5:45 p.m., 5-min service, university-operated (Figure 6).

The I System has been an overwhelming success. Student rides taken during the first semester totaled 1.8 million. Of these, 800,000 were taken on the new campus network and 1 million were taken on the city system. Between August and December of 1989, the #21 Quad Route averaged 120 passengers per revenue-hour, whereas the #22 Illini route averaged 52 passengers per revenue hour.

Since the implementation of the I System, the CUMTD has increased its productivity and its value to the community. A comparison of fiscal year 1989 to 1990 demonstrates the positive impact the new campus service has had on CUMTD system-wide efficiency and effectiveness. For fiscal year 1990, ridership has approximately doubled over the same period for previous year, from 2,796,120 rides in 1989 to 5,449,317 in 1990. In addition, operating revenues increased by 54 percent, whereas operating expenses increased only by 21 percent. Passenger revenue per revenue-vehicle-hour has increased over 40 percent to $12.10 per revenue-vehicle-hour. Likewise, unlinked passenger trips per revenue-vehicle-hour have increased to over 40 trips per hour, an increase of approximately 64 percent over 1989 (*3*). Table 3 presents a comparative summary of the impacts of the new I System on significant operating statistics for fiscal years to date of 1989 and 1990.

Because of the success of the I System and supportive TSM measures, the university has postponed plans for the construction of three 500-space parking structures at a cost of over $5 million. For less than 5 percent of the cost of constructing these parking garages, the university has subsidized 623 full-time faculty and staff members' annual bus passes. Over 500 participants have enrolled in the university-sponsored low-cost carpool, ride share program, and remote parking program. These programs, combined with the bus subsidy program, have reduced the demand for parking by over 1,000 spaces (*8*). By supporting these complementary programs, the university avoided the costly annual amortization, operating, and maintenance costs associated with the construction of new parking garages.

Another related benefit of the I System has been the decline of student-registered vehicles on campus. According to the Parking Division there has been a 30 percent decrease of student-registered cars on campus from 6,523 in academic year 1988 to 4,558 in 1990 (see Figure 7).

Finally, and most importantly, the students have a comprehensive transportation system that addresses their unique needs. For only $10 per semester, students have unlimited access to the university as well as to the city system, providing them with employment, housing, cultural, shopping, and recreational opportunities that may have been previously denied.

TABLE 3 IMPACTS OF THE NEW I SYSTEM ON CUMTD OPERATING STATISTICS, 1989 VERSUS 1990

	Fiscal Year 1989	Fiscal Year 1990	Percent Change
Operating Revenues	1,245,336	1,925,125	54.6%
Operating Expenses	4,818,256	5,841,604	21.2%
Operating Cost Recovery Ratio	25.85%	32.96%	27.5%
Passenger Revenue per Revenue Vehicle Hour	$8.64	$12.10	40.0%
Ridership (Unlinked Trips)	2,796,120	5,449,317	94.9%
Unlinked Passenger Trips per Revenue Vehicle Hour	24.71	40.71	64.8%

Source: Operating Statistics, Champaign-Urbana Mass Transit District. Fiscal Year 1989 and 1990.

On campus, the I System provides an important link in an increasingly expanding and disjointed campus.

A random survey of students was undertaken during the 1990 spring semester to measure the level of usage and to measure students' perceptions of the campus community bus service. Over 75 percent of the people surveyed indicated they had used the campus community service at least once during the school year, which, when factored up would represent 25,691 students that have at least tried the system. In general, over 70 percent of the respondents indicated they were satisfied to very satisfied with six of the categories; days on which buses run, hours buses run each day, vehicle comfort and cleanliness, vehicle safety, driver courtesy, and amount of service on campus. Of the three categories that had under a 70 percent satisfaction rate, the how often buses run category still had over a 60 percent satisfaction rating. The only two categories that fell under the 60 percent satisfaction level were buses arriving on time at 58.6 percent and passenger capacity (over-crowding), 43.9 percent (*9*).

NEW DIRECTIONS

A third student-wide referendum held in March 1990 was successful in making the I System permanent. Of the 3,000 votes cast, 88 percent voted for making the I System permanent with the establishment of a $13 per semester fee. In addition, the university agreed to increase its participation in the I System, providing $230,000 per year over 3 years. In the Fall of 1990, the CUMTD will take over the #23 remote parking shuttle route, previously operated by the university, representing 15,000 hours of extra service.

The university is also committed to continue subsidizing bus passes, promoting low-cost parking for shared-ride users, remote parking with shuttle service and incremental increases in the cost of reserved faculty and staff parking. It has also raised meter rates from 25 to 50 cents per year while maintaining a fee of $30 per year for parking in the remote commuter lot.

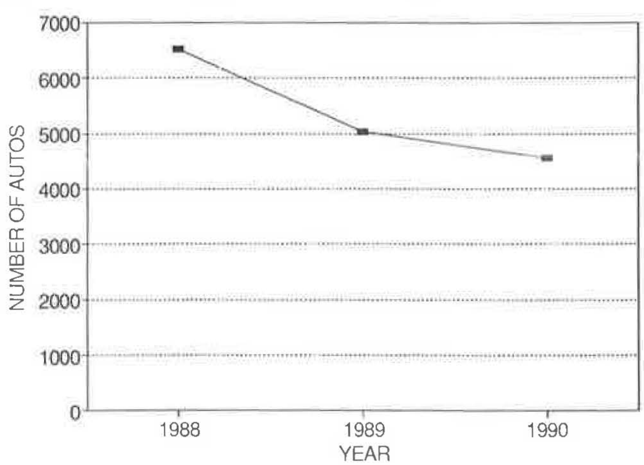
CONCLUSION

The successful results of the recently implemented campus-community I System demonstrate that transit can play a new and leading role in improving mobility within an expanding and dispersed campus environment in a cost-effective manner. The establishment of the original concept to a permanent goal of campus-community bus system evolved over the course of 5 years. It took three student referendums, a change in university parking policy, and the active participation of the university for the goal to be realized.

Important insights can be gained from this experience, primarily, that a successful plan must be comprehensive. Traffic patterns and the allocation of parking may be part of the problem as well as part of a solution. A system that responds to the mobility and safety needs of the students, faculty, and staff members needs to be designed. For the students, this is accomplished by a providing unlimited access using a free-fare high-frequency circulating intracampus service that is integrated with the regular city system. This integrated campus-community system intercepts off-campus students and other users at the point of origin, thus avoiding the attendant problems with automobile commuting to campus, and provides an easy system to access dispersed university activity centers.

In addition, the success of the I System is linked to the complementary and comprehensive TSM measures implemented by the university. These measures have included both incentives and disincentives, such as 80 percent employer-subsidized transit passes, reduced parking rates for shared-ride users and for parkers using remote parking lots, and finally, escalating increases in the cost of central campus reserved parking spaces.

The success of this program has resulted in the university's postponing the construction of $5 million worth of parking garages on campus. A comprehensive approach that maximizes the use of existing resources, with transit as a centerpiece, is a cost-effective solution to the traffic, transportation, and mobility problems that plague urbanizing universities.



Source: University of Illinois, Parking Division. Parking Statistics 1990.

FIGURE 7 Student automobile registrations of U of I.

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Temporal Effects of Incidents on Transit Ridership in Orange County, California

ERIK FERGUSON

Aggregate level transit ridership forecasting models often are based on time series data, with potential serial autocorrelation properties that can bias parameter estimates upward and error estimates downward, and skew forecasting confidence intervals and their resulting interpretation significantly. A combined time series and cross-sectional regression model of transit ridership is developed that incorporates temporal variations as well as supply, demand, and pricing characteristics of the market for transit services in Orange County, California, between 1973 and 1989. It was found that Orange County transit ridership exhibits significant serial and seasonal fluctuations, which were captured in the model. The temporary and lingering effects of incidents were also tested. The 1979 oil shortage was shown to have a large positive impact on transit ridership, which dwindled quite rapidly once the oil shortage ended. A work stoppage of 6 weeks' duration in 1981 had a large negative impact on transit ridership, which dwindled only slowly. A shorter work stoppage in 1986, during which limited service was provided by transit agency administrative personnel, had a much smaller negative impact than the 1981 work stoppage, which dwindled much more rapidly. Transit fare and gasoline pricing variables were found to have no significant effect on transit ridership in the preferred temporally based model. Transit fares did not increase much in real terms over the period covered, and did not reflect variations in transit service provided, being predicated on a simple county-wide flat fare basis. Over 70 percent of all Orange County transit riders were captive riders in 1987, having no car available to them for commuting or other travel purposes, making the price of gasoline basically irrelevant to the majority of such transit riders in the shorter term.

Many problems in urban and regional transportation analysis have important temporal dimensions. Forecasting changes in employment, population, or travel behavior are just a few examples of areas where temporal processes and interactions may be important in identifying existing conditions, explaining past trends, or forecasting future outcomes of urban and regional policies and planning. Time series analysis is one method of explicitly incorporating temporal phenomena in regression analysis for forecasting purposes. Time series analysis often is used as a projection method, based exclusively on the past performance of specific exogenous output variables. Policy input variables, such as spatial or socioeconomic variations in demand, often are not included in time series models, because of lack of data, lack of analysis software, or both.

Cross-sectional models typically provide more opportunities for testing policy sensitivity. However, parameters and confidence intervals estimated in cross-sectional models may be biased significantly, if serial autocorrelation is present. Combined time series and cross-sectional models offer the possibility of providing policy sensitivity and controlling for temporal estimation biases simultaneously. Simultaneous time-series and cross-sectional regression analysis are applied to transit ridership forecasting, assuming only first-order, serial autoregressive processes are involved (*1*). Three types of temporal variability are included in this analysis:

1. First-order serially autoregressive impacts;
2. First-order seasonally autoregressive impacts; and
3. Permanent, temporary, and lingering impacts of incidents over time.

Quarterly transit ridership data are used to demonstrate how alternative model formulations can be evaluated in terms of descriptive ability (overall goodness of fit), serial autocorrelation (parameter estimation bias), and predictive ability (forecast error).

First, some of the basic statistical and econometric principles required to conduct an exploratory analysis of this type are described. Second, various transit ridership model variations formulated to test these ideas using original data collected in Orange County, California, are compared and contrasted. Finally, some of the policy and research implications derived from a comparative evaluation of the various model results are reported.

DATA

The data used in this analysis were taken from the Orange County Transit District (OCTD) aggregate, or system-wide, transit ridership forecasting model. Variations on the temporal model discussed here were tested by the author while employed by OCTD from 1986 to 1988. A version of the model discussed here was developed independently by the Center for Economic Research at Chapman College (*2*), and is now in use by OCTD for transit ridership forecasting purposes. The Chapman College model is used to forecast transit ridership in Orange County 5 years in advance for financial and service planning purposes. In addition, the model is used to comply with the requirements of the regional transportation planning process, as administered by OCTD, the Southern California Association of Governments, the Orange County Transportation Commission, the State of California Department of Transportation, and other responsible public agencies in the region.

OCTD has been in operation for close to 20 years, beginning in the fourth quarter of 1973, after the first Arab oil embargo occurred. Quarterly transit ridership data are de-

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rived from a unique, stratified random sample of driver trip sheets, and adjusted using method of fare payment and fare data. The accuracy of this data is good, with an expected annual statistical measurement error of not more than ± 2 percent at the 95 percent confidence interval (*3*). Vehicle service miles, a supply measure, is even more accurate, as the length of all bus runs driven is known, and measured to within the nearest 10th of a vehicle-mile in service. Average county-wide employment figures, used in this analysis both as a reasonable and a reliable proxy measure of demand, are derived from Chapman College's annual forecast of Orange County employment, and are equally reliable in measurement. Over half of all person-trips made on the Orange County transit system are work-related trips, with a large part of the remainder school and recreational activities.

All other data used in this analysis are temporal in nature, and are not subject to sampling or measurement errors, at least not in the same sense that the cross-sectional variables just described might be.

METHODOLOGY

A variety of models are described, tested, and compared in this analysis. The principal types of models used include cross-sectional models, first-order autoregressive models (*4*), combined time series and cross-sectional models (*5*), seasonally adjusted combined models, and incident impact models. Evaluation measures include the traditional cross-sectional measures of overall goodness-of-fit and the magnitude and direction of independent variable effects, as well as two measures of serial autocorrelation, Durbin-Watson's *d* (*6*), for models without lagged endogenous variables (*7*), and Durbin's *h* (*8*), for models with lagged endogenous variables (*9*).

Basic Cross-Sectional and Time-Series Models

A traditional cross-sectional transit ridership forecasting model is as follows:

$$PAS_t = b_0 + b_1 * VSM_t + b_2 * EMP_t + e_t \qquad (1)$$

where

PAS_t = total transit ridership in time period t,
VSM_t = total vehicle service miles in time period t,
EMP_t = average service area employment in time period t,
e_t = error in prediction associated with the observation of total transit ridership in time period t, and
b_0, b_1, b_2 = parameters to be estimated.

A slight modification of this equation results in the familiar double-log econometric regression model, which provides direct measures of the elasticity of demand for the dependent variable (total transit ridership) with respect to each independent variable (total vehicle service-miles and average quarterly employment). The double-log model has proven to be useful for public and private policy sensitivity analysis in a variety of cases, and will be relied on throughout the remainder of this analysis:

$$\ln(PAS_t) = b_0 + b_1 * \ln(VSM_t) + b_2 * \ln(EMP_t) + e_t \qquad (2)$$

If a time series variable, such as quarterly transit ridership, is subject to serial autocorrelation of the error terms in prediction, the resulting parameter estimates may be severely biased, with overall goodness of fit measures and parameter standard error terms similarly biased by the existence of serial autocorrelation. A commonly used and powerful test of serial autocorrelation in regression analysis is Durbin-Watson's *d*:

$$d = \frac{\sum (e_t - e_{t-1})^2}{\sum (e_t)^2} \qquad (3)$$

where

d = Durbin-Watson's d, and
e_{t-1} = error in prediction associated with the observation of total transit ridership in the preceding time period, $t - 1$.

Values of *d* around 2 indicate the existence of no significant serial autocorrelation. Values of *d* close to 0 suggest positive serial autocorrelation, whereas values of *d* close to 4 suggest negative serial autocorrelation. If significant serial autocorrelation is identified, a lagged endogenous variable may be used to estimate an autoregressive time series regression model, on the basis of a normal first order autoregressive process, as follows:

$$\ln(PAS_t) = b_0 + b_1 * \ln(PAS_{t-1}) \qquad (4)$$

where PAS_{t-1} is the total transit ridership in the immediately preceding time period, $t - 1$.

Such a model may still be biased by residual or higher order levels of serial autocorrelation. Durbin-Watson's *d* does not provide a reliable measure of serial autocorrelation in models that include lagged endogenous variables as independent variables. In such cases, Durbin's *h* may be used in place of Durbin-Watson's *d*, as a more reliable indicator of serial autocorrelation:

$$h = p * \left[\frac{T}{1 - T * \text{var}(b_\cdot)}\right]^{1/2} \qquad (5)$$

where

h = Durbin's h;
p = $1 - d/2$;
T = total number of observations on which the regression model is based (not degrees of freedom), i.e., sample size; and
$\text{var}(b_\cdot)$ = variance of $b_\cdot$, or square of the estimated standard error term for $b_\cdot$, where $b_\cdot$ is the parameter estimate of the first-order lagged endogenous variable $[\ln(PAS_{t-1})]$, regardless of whether any other serially related exogenous or endogenous variables are included in the model.

A combined time series and cross-sectional transit ridership forecasting model would be as follows:

$$\ln(PAS_t) = b_0 + b_1 * \ln(VSM_t) + b_2 * \ln(EMP_t) + b_3 * \ln(PAS_{t-1}) + e_t \qquad (6)$$

Other Types of Serial Processes

In addition to first-order autoregressive processes, many other types of serial autocorrelation are theoretically possible. Differenced models, in which the dependent variable is defined as the difference between ridership in time period t and ridership in some previous time period, $t - n$, may also be relevant in some cases, as are moving-average models, in which the dependent variable is hypothesized to be influenced by the weighted average of transit ridership over several time periods, which may include before and after time periods in estimation.

These analytically more complex types of models require the estimation of error terms in separate models are the use of instrumental variables in estimating final regression equations (*4*). Such models are usually neither necessary nor relevant in practice, often do not require direct estimation in any case, and are not further considered here. This implies that the temporal processes influencing aggregate transit ridership are relatively simple and straightforward, an assumption that will be tested explicitly as part of the development of the final recommended transit ridership forecasting model.

Seasonal Models

A second type of direct serial autocorrelation is seasonal autoregressivity. In this example, the length of seasonality is 4, because there are four quarters in each year. One formulation of such a seasonal model, which retains a first-order, lagged endogenous variable and cross-sectional variables as before, is as follows:

$$\ln(\text{PAS}_t) = b_0 + b_1 * \ln(\text{VSM}_t) + b_2 * \ln(\text{EMP}_t) + b_3 * \ln(\text{PAS}_{t-1}) + b_4 * \ln(\text{PAS}_{t-n}) + e_t \quad (7)$$

where n is the length of seasonality.

Alternatively, seasonality may be included in the model through the use of dummy variables. Each seasonal dummy variable tests for differences in transit ridership between that season and an arbitrary reference season, which may be any of the four quarters, as follows:

$$\ln(\text{PAS}_t) = b_0 + b_1 * \ln(\text{VSM}_t) + b_2 * \ln(\text{EMP}_t) + b_3 * \ln(\text{PAS}_{t-1}) + b_4 * \text{SEA}_1 + b_5 * \text{SEA}_2 \ldots + b_x * \text{SEA}_{n-1} + e_t \quad (8)$$

where SEA_x is 1 if the observed total transit ridership occurred in season n, and is 0 otherwise.

The choice of which alternative seasonal model formulation to use may be influenced by the length of seasonality. When the number of seasons (quarters, months, weeks, days, hours, etc.) is relatively small, collinearity between the first-order autoregressive term and the seasonal term will tend to be higher, suggesting the use of seasonal dummy variables. When the number of seasons is relatively high, the loss of efficiency in model estimation because of the necessary inclusion of $n - 1$ independent variables will tend to be higher, suggesting the use of a seasonally differenced term as an independent variable.

Incident Models

An incident is any event that disturbs the observed relationships between a dependent variable and any or all of its associated time-series and cross-sectional explanatory variables. Examples of incidents in the transit industry might include a large scale restructuring of transit services (the introduction of a new rail service, where before there was none, for example), significant fare restructuring, gas shortages, oil price increases, ambitious marketing programs, and perhaps the classic example, the transit work stoppage, or labor strike (*10*). Such incidents may have transit ridership impacts which are positive or negative, abrupt or gradual, temporary or permanent, in nature. A simple model of any or all of these types of effects is as follows:

$$\ln(\text{PAS}_t) = b_0 + b_1 * \ln(\text{VSM}_t) + b_2 * \ln(\text{EMP}_t) + b_3 * \ln(\text{PAS}_{t-1}) + b_4 * \text{SEA}_1 + b_5 * \text{SEA}_2 + b_6 * \text{SEA}_3 + b_7 * \text{INC}_s * e^{(s-1)*\delta} + e_t \quad (9)$$

where

INC_s = 1 in time period s, during which the incident actually occurred and in all subsequent time periods as well, 0 otherwise;

s = time period, where s is measured in the standard time periods used in model construction, beginning with $s = 1$ in that time period during which the incident actually occurred; and

δ = exponential decay parameter, theoretically or empirically derived, which provides a measure of the (constant) rate at which an incident's effect changes over time (Table 1).

It is possible that an incident may have one level of impact in the time period during which it occurs, and an entirely different level of impact in subsequent time periods. A good example of this is the effect of a work stoppage on transit ridership. It is common knowledge in the transit industry that work stoppages can affect transit ridership long after a strike has ended. While the strike is in progress, no transit service is provided at all, and thus no one may ride transit anywhere in the affected service area. Transit riders must then seek out alternative means of transportation (automobile, walking, etc.), or forgo their customary travel behavior. After the strike ends, individuals may choose to take one or more of the following actions for different types of trips:

1. They may revert immediately to their former customary travel behavior (i.e., get back on the bus);
2. They may permanently change their travel behavior (i.e., purchase a private automobile for their own personal use; or
3. They may delay changing their behavior, but ultimately wind up reverting to their former customary travel behavior

TABLE 1 NUMERICAL RELATIONSHIP BETWEEN DELTA AND INCIDENT EFFECTS

Value of delta (decay factor)	Effect of incident over time
Positive	Permanent, and increasing over time.
0	Permanent, and constant over time.
Negative	Temporary and lingering, that is, decreasing constantly over time.
Negative and very large i.e., negative infinity)	Temporary and abrupt, because the effect vanishes immediately, once the stimulus has been removed.

(e.g., to keep up their end of a carpool arrangement for a certain length of time).

Depending on the length and severity of the incident, individual travellers may wait longer or shorter periods of time before returning to their former customary behavior patterns. It is difficult if not impossible to model different kinds of temporal processes that occur simultaneously, explicitly in the context of time series analysis, just as the effects of separate incidents that occur at the same time cannot be isolated in a single aggregate forecasting model. It is possible to separate the temporary effect of one incident from the more or less permanent aftereffects of that same incident as follows:

$$\begin{aligned}\ln(PAS_t) = {} & b_0 + b_1 * \ln(VSM_t) + b_2 * \ln(EMP_t) \\ & + b_3 * \ln(PAS_{t-1}) + b_4 * SEA_1 \\ & + b_5 * SEA_2 + b_6 * SEA_3 \\ & + b_7 * INC_s + INC_{s+1} * e^{(s-1)*\delta} + e_t \qquad (10)\end{aligned}$$

where

INC_s = 1 in time period s only, when the incident actually occurred, 0 otherwise; and

INC_{s+1} = 1 in time period s + 1, immediately after the incident occurred, and 1 in all subsequent time periods, 0 otherwise.

The analytical results of each of these types of transit ridership forecasting models will be compared in the next section, with conclusions drawn concerning model validity, and their potential utility in public policy analysis. The primary data used in the model are shown in Figure 1. Orange County employment increased with few interruptions, from less than 500,000 in 1973 to well over 1,000,000 in 1989. OCTD transit service (VSM) expanded rapidly during the 1970s, but remained virtually constant during the 1980s. OCTD ridership nonetheless continued to increase in the 1980s, though at a much lower annual growth rate than in the 1970s.

RESULTS

Analytical results from a variety of model formulations are compared in terms of internal validity. Internal validity is composed of the statistical measures that explain the significance of estimated parameters, and the existence of measurement errors associated with collinearity or serial autocorrelation. External validity could also be checked by comparing these model results with those from other transit ridership forecasting models, and actual transit performance in future time periods.

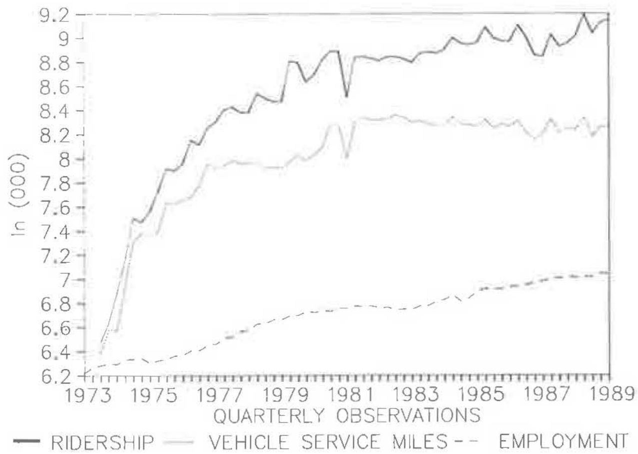

FIGURE 1 Orange County, California, trends.

Basic Models

Table 2 presents results for basic cross-sectional, autoregressive time-series, and combined transit ridership forecasting models. All three models show significant serial autocorrelation in the distribution of error terms, indicating that model parameters may be biased in terms of magnitude, confidence level, or both. Parameter estimates for the simple cross-sectional and time series models are clearly too high by industry standards. Transit service elasticities generally range from +0.3 to +0.7, whereas the estimated parameter for VSM in Model 1.1 is greater than +1. The Model 1.2 results suggest that 90 percent of transit ridership is retained from one quarter to the next, but this is probably much too high as a measure of elasticity for individual transit riders. Model 1.3 is clearly preferred, with more appropriate parameter estimates for all three of the included variables. However, serial autocorrelation appears to be a slight problem even in Model 1.3.

A few observations in each model indicate relatively high studentized residuals, identifying such observations as outliers. Heteroskedasticity (ordinary dependent variable autocorrelation) does not appear to be a problem in any of the

TABLE 2 BASIC CROSS-SECTIONAL, TIME SERIES, AND COMBINED TRANSIT RIDERSHIP FORECASTING MODELS

	Alternative Model Formulations[1]		
Model	1.1	1.2	1.3
Independent Variables	Cross-Sectional[2]	Time-Series[3]	Combined[4]
Intercept	-4.708	0.926	-2.888
$\ln(VSM_t)$	1.037 (0.043)		0.678 (0.095)
$\ln(EMP_t)$	0.740 (0.082)		0.511 (0.101)
$\ln(PAS_{t-1})$		0.896 (0.023)	0.304 (0.078)
Number of Observations	63	62	62
Degrees of Freedom	60	60	58
R^2	0.9808	0.9633	0.9820
Durbin-Watson's d	0.89		
Durbin's h		2.30	2.03

1. The dependent variable in each case is $\ln(PAS_t)$.
2. Basic cross-sectional model, including measures of supply and demand.
3. Basic first order autoregressive time-series model.
4. Combined cross-sectional and time-series model.

Note: Standard errors for all independent variables are given in parentheses next to each parameter estimate. All parameter estimates listed in this table are significant at the 0.05 level of confidence or higher, using a one-tailed test.

models. Serial autocorrelation is indicated when error terms tend to stay on one side or another of the origin (0), rather than bouncing back and forth randomly. All three models exhibit serial autocorrelation. An additional step would be necessary to correct for continued serial autocorrelation in the combined model. However, error models and instrumental variables are to be avoided because of complexity and inconvenience in spreadsheet applications. Analysts might refer to more sophisticated application techniques and computer software programs in such cases.

Seasonal Models

Table 3 presents results from combined cross-sectional and time series models with additional seasonally autoregressive terms introduced. There are two methods for incorporating seasonal autoregressivity into regression analysis, one using seasonally differenced variables, the other using seasonal dummy variables. Model 2.1 uses a seasonally differenced variable with the combined transit ridership forecasting model. Parameter estimates are generally lower for combined model variables, though Durbin's h is extremely high. This model is overdifferenced; collinearity between the seasonally and nonseasonally differenced variables has biased parameter estimates severely. Model 2.2 uses three seasonal dummy variables to account for ridership differences among quarters, with the fourth quarter as the implied baseline. Two of the three quarterly dummy variables are not significant, yet Durbin's h is less than 1.64, implying that serial autocorrelation in the distribution of error terms is no longer a significant problem in model estimation. Thus, Model 2.2 is preferred over Model 2.1.

Figures 2 and 3 show serial autocorrelation for Models 2.1 and 2.2. Figure 2 shows the effect of overdifferencing on error terms in estimation. Figure 3 shows a notable reduction in serial autocorrelation, but two observations associated with incidents clearly act as outliers in model estimation. In both graphs, error terms in prediction are shown in relation to the dependent variable on the x-axis, and temporally with a linear time path.

Incident Models: Theoretical Tests

Table 4 presents results from the combined model with seasonal dummy variables and incident effects included. Model 3.1 assumes the effects of all three incidents, the 1979 gas shortage and the 1981 and 1986 work stoppages, to be temporary and abrupt, that is, that all effects vanish as soon as the incident is over. Model 3.3 assumes that the effects of all three incidents are permanent and abrupt, that is, that each incident has the same effect in all subsequent quarters that it has in the quarter in which it actually occurs. Model 3.2 assumes that the effects of all three incidents are temporary but lingering, with the rate of decay (delta) arbitrarily set at -1, which assumes a constant decline in parameter significance of 68 percent per quarter. Signs are as expected for every variable in all three models, although the 1986 strike effect is not significant for either extreme case, nor is the 1979 gas shortage effect significant under a permanent effects scenario. The temporary, lingering effects scenario (Model 3.2) provides the best overall goodness of fit, and the lowest Durbin's h value, with all variables significant and all signs as expected.

Incident Models: Empirical Tests

Table 5 presents results from the combined model based on empirically tested (or bootstrapped) best-fit identification of

TABLE 3 SEASONAL TRANSIT RIDERSHIP FORECASTING MODELS

	Alternative Model Formulations[1]	
Model	**2.1**	**2.2**
Independent Variables	**Seasonal Difference Variable[2]**	**Seasonal Dummy Variables[3]**
Intercept	-1.530	-2.252
ln(VSM)	0.467 (0.115)	0.535 (0.085)
ln(EMP)	0.521 (0.116)	0.430 (0.088)
$\ln(PAS_{t-1})$	0.106 (0.094)@	0.423 (0.071)
$\ln(PAS_{t-4})$	0.233 (0.077)	
SEA_1		0.022 (0.023)@
SEA_2		0.124 (0.025)
SEA_3		0.040 (0.024)@
Number of Observations	59	62
Degrees of Freedom	54	55
R^2	0.9739	0.9880
Durbin's h	7.92	1.30

1. The dependent variable in each case is $\ln(PAS_t)$.
2. Including a seasonally differenced measure of transit ridership as an independent variable, in addition to the first order autoregressive term.
3. Including three dummy variables representing relative transit ridership differences between the first and fourth, second and fourth, and third and fourth quarters of the year, respectively.

Note: Standard errors for all independent variables are given in parentheses next to each parameter estimate. All parameter estimates listed in this table are significant at the 0.05 level of confidence or higher, using a one-tailed test. Those parameter estimates marked with an @ are not significant at the 0.05 level.

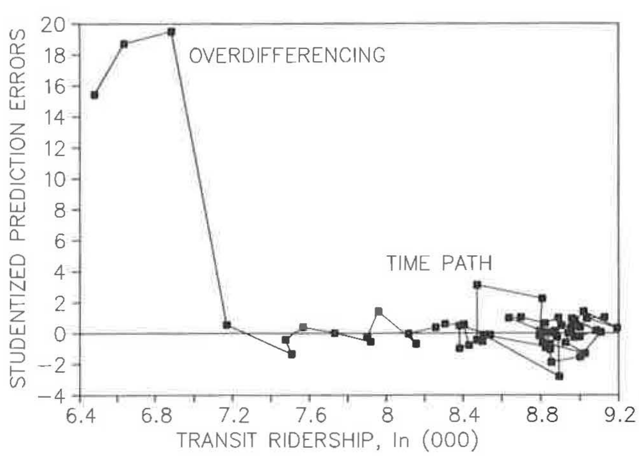

FIGURE 2 Serial autocorrelation, Model 2.1.

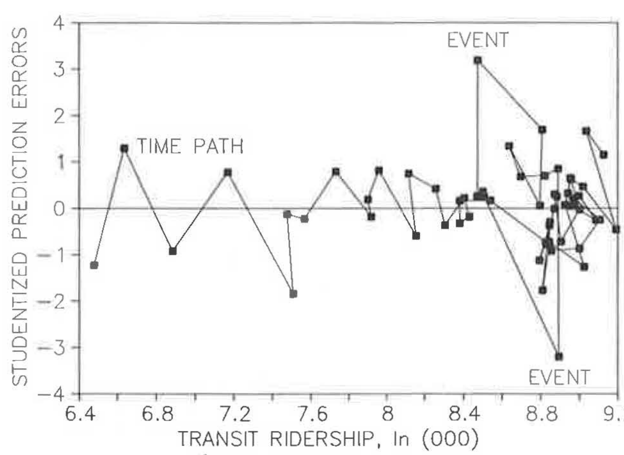

FIGURE 3 Serial autocorrelation, Model 2.2.

decay parameter values for each incident. Model 4.1 assumes exponential decay parameters to be the same for all incidents, whereas Model 4.2 relaxes this restriction, allowing all decay parameters to vary independently. Both of these models have higher R^2 values, but also greater serial autocorrelation measures, than Model 3.3. Without any guidance on how to combine these two model evaluation measures into one unique qualifier, modelers will have to choose between them when ambiguous results are achieved, as in this case.

Incident Models: Abrupt and Lingering Effects Separated

Table 6 presents analytical results with temporary (abrupt) and lingering (permanent) effects of each incident modeled separately using independent variables for each such effect. Model 5.1 includes all available observations in estimation, whereas Model 5.2 excludes the first two observations in the temporal sequence of quarterly OCTD ridership that has oc-

TABLE 4 INCIDENT-RELATED TRANSIT RIDERSHIP FORECASTING MODELS: THEORETICALLY DERIVED COMBINED EFFECTS

	Alternative Model Formulations[1]		
Model	**3.1**	**3.2**	**3.3**
Independent Variables	**Temporary, Abrupt Effects**[2]	**Temporary, Lingering Effects**[3]	**Constant, Permanent Effects**[4]
Intercept	-1.853	-2.458	-4.500
ln(VSM)	0.441 (0.072)	0.549 (0.067)	0.689 (0.077)
ln(EMP)	0.380 (0.070)	0.462 (0.069)	0.783 (0.137)
$\ln(PAS_{t-1})$	0.504 (0.060)	0.408 (0.056)	0.271 (0.067)
SEA_1	0.033 (0.019)	0.032 (0.018)	0.032 (0.019)
SEA_2	0.113 (0.020)	0.108 (0.019)	0.111 (0.021)
SEA_3	0.033 (0.019)	0.032 (0.018)	0.048 (0.020)
$GAS79_{a,l}$	0.217 (0.053)	0.234 (0.049)	0.038 (0.032)@
$STR81_{a,l}$	-0.253 (0.056)	-0.192 (0.049)	-0.146 (0.027)
$STR86_{a,l}$	-0.073 (0.054)@	-0.091 (0.050)	-0.020 (0.029)@
Number of Observations	62	62	62
Degrees of Freedom	52	52	52
R^2	0.9932	0.9935	0.9923
Durbin's h	0.42	0.16	1.61

1. The dependent variable in each case is $\ln(PAS_t)$.
2. Assuming that the exponential decay parameter for each independent lingering effect variable is equal to negative infinity. In essence, each incident affects transit ridership only in that quarter in which the incident actually occurs. Immediately thereafter, the incident's effect on transit ridership reduces to zero, and remains there.
3. Assuming that the exponential decay parameter for each independent lingering effect variable is equal to -1.0.
4. Assuming that the exponential decay parameter for each independent lingering effect variable is exactly equal to zero. In essence, each incident affects transit ridership permanently by a given percentage, beginning in that quarter in which the incident actually occurs, and continuing forever after.

Note: Standard errors for all independent variables are given in parentheses next to each parameter estimate. All parameter estimates listed in this table are significant at the 0.05 level of confidence or higher, using a one-tailed test. Those parameter estimates marked with an @ are not significant at the 0.05 level.

TABLE 5 INCIDENT-RELATED TRANSIT RIDERSHIP FORECASTING MODELS: EMPIRICALLY DERIVED COMBINED EFFECTS

Model	Alternative Model Formulations[1] 4.1	4.2
Independent Variables	**Equal Exponential Decay Parameters[2]**	**Varying Exponential Decay Parameters[3]**
Intercept	-3.529	-4.237
$\ln(VSM)$	0.714 (0.064)	0.772 (0.059)
$\ln(EMP)$	0.609 (0.073)	0.694 (0.067)
$\ln(PAS_{t-1})$	0.265 (0.054)	0.229 (0.048)
SEA_1	0.034 (0.016)	0.032 (0.014)
SEA_2	0.105 (0.017)	0.095 (0.016)
SEA_3	0.041 (0.017)	0.039 (0.015)
$GAS79_{a,l}$	0.159 (0.031)	0.200 (0.039)
$STR81_{a,l}$	-0.191 (0.031)	-0.157 (0.024)
$STR86_{a,l}$	-0.094 (0.036)	-0.129 (0.033)
Number of Observations	62	62
Degrees of Freedom	52	52
R^2	0.9946	0.9957
Durbin's h	0.27	1.47

1. The dependent variable in each case is $\ln(PAS_t)$.
2. Assuming that the exponential decay parameter for each combined abrupt, lingering effect variable is equal to -0.20. This assumption maximizes goodness of fit (R^2), given that the exponential decay parameters for all incident variables must be exactly identical. Derived through iteration.
3. Assuming that the exponential decay parameter for the 1979 gas shortage variable is equal to -0.68, for the 1981 work stoppage variable is equal to -0.06, and for the 1986 work stoppage variable is equal to -0.21. These assumptions maximize goodness-of-fit (R^2), given that exponential decay parameters for incident variables are allowed to vary independently. This solution was arrived at through an iterative process, beginning with marginal adjustments in the exponential decay parameters for each of the three incident variables sequentially, and ending when no further exponential decay parameter adjustment yielded an increase in R^2. The iterative order in which adjustments were made did not affect the final outcome in this example. Failure to converge to a unique solution, independent of the path taken, might have indicated model specification problems, which were not in evidence here.

Note: Standard errors for all independent variables are given in parentheses next to each parameter estimate. All parameter estimates listed in this table are significant at the 0.05 level of confidence or higher, using a one-tailed test.

TABLE 6 INCIDENT-RELATED TRANSIT RIDERSHIP FORECASTING MODELS: ABRUPT AND LINGERING EFFECTS SEPARATED

	Alternative Model Formulations[1]	
Model	**5.1**	**5.2**
Independent Variables	**All Observations Employed[2]**	**First Two Observations Removed[3]**
Intercept	-4.215	-4.532
ln(VSM)	0.725 (0.072)	0.824 (0.072)
ln(EMP)	0.707 (0.077)	0.707 (0.071)
ln(PAS_{t-1})	0.262 (0.060)	0.207 (0.055)
SEA_1	0.040 (0.014)	0.030 (0.013)
SEA_2	0.101 (0.015)	0.094 (0.014)
SEA_3	0.039 (0.015)	0.038 (0.013)
$GAS79_a$	0.187 (0.041)	0.192 (0.036)
$STR81_a$	-0.227 (0.044)	-0.197 (0.039)
$STR86_a$	-0.073 (0.042)	-0.068 (0.037)
$GAS79_l$	0.110 (0.042)	0.119 (0.037)
$STR81_l$	-0.131 (0.025)	-0.152 (0.024)
$STR86_l$	-0.151 (0.037)	-0.154 (0.033)
Number of Observations	62	60
Degrees of Freedom	49	47
R^2	0.9962	0.9957
Durbin's h	1.56	0.89

1. The dependent variable in each case is ln(PAS_t).
2. The empirically derived exponential decay parameters which provided the best overall goodness-of-fit in Model 5.1 were -infinity for the 1979 gas shortage lingering effects variable, -0.040 for the 1981 work stoppage lingering effects variable, and -0.32 for the 1986 work stoppage lingering effects variable.
3. The empirically derived exponential decay parameters which provided the best overall goodness-of-fit in Model 5.2 were -1.1 for the 1979 gas shortage lingering effects variable, -0.051 for the 1981 work stoppage lingering effects variable, and -0.32 for the 1986 work stoppage lingering effects variable.

Note: Standard errors for all independent variables are given in parentheses next to each parameter estimate. All parameter estimates listed in this table are significant at the 0.05 level of confidence or higher, using a one-tailed test. Those parameter estimates marked with an @ are not significant at the 0.05 level.

curred since 1973. In this case, Model 5.2 has lower serial autocorrelation, but also a lower R^2, than Model 5.1. Figure 4 shows serial autocorrelation for Model 5.1, the theoretically least restricted, and thus preferred, model, with full incident effects, and all observations included. Although serial auto-

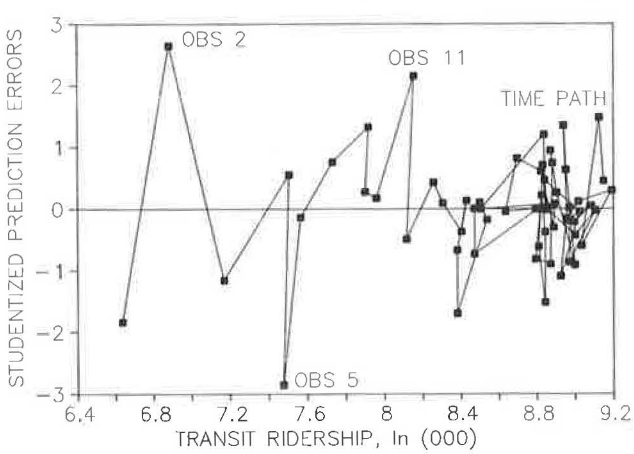

FIGURE 4 Serial autocorrelation, Model 5.1.

correlation is acceptable (barely), and the independent effect of all three incidents has been accounted for successfully, three new observations appear as outliers, all three occurring relatively early in OCTD's history. These three observations cannot be modeled easily as incidents, although they may be related to the 1973 oil crisis, or major service expansions. The primary reason for this inability to model such incidents is lack of data. OCTD did not begin operations until 1973. It is thus impossible to know exactly what equilibrium transit ridership would have been in Orange County before start-up in 1973. Without prior data, it is dangerous and sometimes highly inaccurate to try to model the aftereffects of specific incidents.

Another method of dealing with outlier observations is to eliminate them from the analysis. In the case of time series analysis, however, observations cannot be plucked at random from the data base. A continuous stream of data is required. This suggests that observations could be modified in value to conform to model predictions (a somewhat dubious practice), or entire segments of data including outliers could be eliminated from the beginning or end of the contiguous time series. Model 5.1 was reestimated with the first 2, 5, and 11 observations eliminated. With the first two observations removed, R^2 decreased, but so did Durbin's h. It was felt by the author that the loss in R^2 was more than made up for by the reduction in serial autocorrelation in Model 5.2. Removing additional observations from the data resulted in additional reductions in R^2, and also increasing serial autocorrelation in relationship to Model 5.2, and are not further considered.

The effects of incidents on transit ridership using Model 5.2 as the basis for comparison are shown graphically in Figure 5. The 1979 gas shortage is shown to have a large, abrupt, and temporary effect on transit ridership, which virtually disappears once gasoline is no longer in short supply. The 1981 work stoppage was prolonged. No service was provided to patrons during this strike. The result was a large decrease in transit ridership, which did not return to normal for a long time. The 1986 work stoppage was much shorter, and limited service was provided to patrons by trained supervisorial and management personnel under a well-kept secret contingency plan during the strike. The result was a similar loss in ridership to the 1986 work stoppage, which rebounded toward normal levels of patronage much more quickly. Note that the abrupt effect of the 1986 work stoppage was smaller than might be expected, presumably because this strike occurred at the very end of a quarter.

Role of Pricing in Determining Orange County Transit Ridership Trends

The economist in the audience will have noted already the absence of a pricing variable in any of the forecasting models so far presented. This omission was not accidental, but the result of preliminary model testing that found pricing variables to have no significant effect on transit ridership in Orange County, once the effect of incidents had been included. Figure 6 shows pricing trends for automobile (average gasoline price) and transit (average bus fare) over the 15-year study period. Inclusion of a transit price variable in the first and second series of models (Tables 2 and 3) produced significant price elasticities varying around −0.3, the industry standard. However, serial correlation remained a problem in these models. When transit pricing was included in the incident impact models (Tables 4–6), the elasticities dropped to a range of about −0.03 to −0.06, and were no longer found to be significant. Similarly, gasoline prices were not found to have a significant independent effect on transit ridership in any of the models considered here.

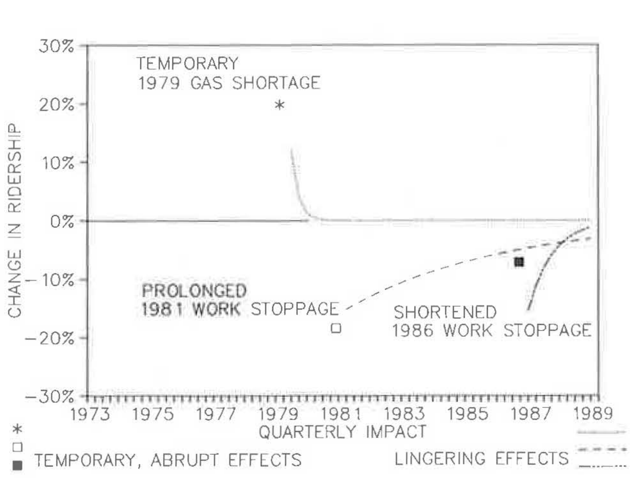

FIGURE 5 Effects of incidents on transit ridership.

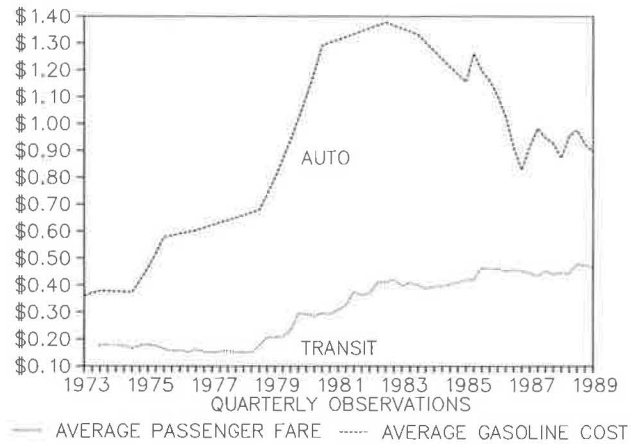

FIGURE 6 Trends in pricing.

The Chapman forecasting model developed for use by OCTD used a transit/automobile price ratio variable that was significant, had a value of −0.3, and was associated with significant serial correlation and parameter biases (*1*). Why does pricing seem to have little if any effect on OCTD transit ridership at the aggregate level of analysis? A review of secular trends in the characteristics of OCTD transit patrons may reveal part of the answer (*11–13*). As Table 7 shows, OCTD patrons increasingly are captive riders making nondiscretionary trips. In 1987, 58 percent of all trips made were work trips, 70 percent of riders were regular users of the system, and 80 percent of patrons had no car available to them to make the trip. Captive riders have low price elasticities of demand for nondiscretionary trips, and virtually zero cross-price elasticities for competitive modes that, like the automobile, are out of reach for them, at least in the near term (*14*). Flat fare systems such as the one used in Orange County often contribute to this lack of price sensitivity on the part of transit patrons (*15*).

Ironically, OCTD financial planning staff recommended implementing a 25-cent fare increase in 5-cent increments over 5 years, to minimize potential transit ridership losses. Taking inflation into consideration, such a policy constitutes maintaining a constant fare over time in real dollars, for which the price elasticity of demand should indeed be 0. These results also reconfirm the notion that OCTD transit ridership increased in 1979 in response to a temporary shortage of gasoline, rather than to a more permanent increase in its price.

CONCLUSIONS

Cross-sectional models are generally evaluated on the basis of theoretical validity, conformance with theoretical expectations concerning the magnitude and direction of change, and overall model goodness-of-fit. Individual parameter estimation error terms and confidence intervals may be significantly biased, if serial autocorrelation of the error terms in prediction is present, for time series dependent variables. In order to prevent temporally related biases from introducing major errors into forecasting models and procedures, various

TABLE 7 SECULAR TRENDS IN OCTD RIDER CHARACTERISTICS

OCTD Rider Characteristics	Year of On-Board Survey			
	1976[1]	1979[1]	1982[2]	1987[3]
Regular Rider[4]	52%	63%	70%	70%
Trip Purpose				
Work	35%	46%	46%	58%[5]
School	35%	25%	26%	18%
Shopping	10%	11%	10%	7%
Recreation	7%	5%	4%	5%
Other	13%	13%	14%	12%
Age				
Under 16	12%	10%	8%	8%
16-64	79%	80%	82%	83%
Over 65	9%	10%	10%	9%
Female	58%	58%	57%	54%
Low Income[6]	74%	55%	51%	45%
No Car Available for Trip	76%	71%	74%	80%
Ethnicity				
White	not asked	not asked	64%	46%
Hispanic			21%	34%
Asian			8%	7%
Black			5%	6%
Sample Size	not available	10,669	21,866	approx. 17,000

1. DMJM and COMSIS Corp., 1981.
2. TRAM, 1983.
3. NuStats, Inc., 1988.
4. Rides five or more days per week.
5. This figure may be high, in that the 1987 system-wide on-board survey sampled bus trips in the a.m. only, rather than all day.
6. Annual household income less than $15,000, *in current dollars.*

techniques are available. Generally, explicit representation of the underlying theoretical temporal processes, through the use of time series transformation of the dependent variable, are required to reduce serial autocorrelation, absent the use of indirect estimation methods that are not discussed here. Ostram (*4*) provides an introduction to indirect estimation techniques, for those who might be interested.

Time series methods include the use of serial and seasonal autoregressive terms, differenced or integrated equations, moving average models, etc. If the independent variables used in the model are influenced by temporal processes, these should be considered, particularly if such "independent" temporal processes are related to those endogenous temporal processes that are known or hypothesized to influence the dependent variable.

Models of the type discussed in this paper may provide more reliable measures of policy sensitivity, as well as more accurate forecasts of future conditions with respect to the dependent variable. These improvements can be tested empirically using ex ante or ex post comparative evaluation measures. Ex ante evaluation requires making a forecast, and waiting for the forecast period to expire before comparing forecast and actual results. Ex post evaluation, or backforecasting, is done by excluding some of the most recently available data from model estimation, and comparing this model output with actual results. Technically, only information on exogenous variables that was available before the backforecast time period should be used in making ex post backforecasts, for the sake of methodological consistency. The model discussed here will probably increase in utility to planners and policy analysts as time series analysis techniques and data become more readily available and understood. Random samples of time series data can be used to lower data collection costs, as long as such data are sampled systematically (*16,17*). The use of such techniques in research and development seems to be increasing. Periodic updating, testing, and evaluation of such time series model results as are in use by practicing planners will enhance understanding and ability to use these versatile methods in the future. Practical advantages of this class of methods should include more accurate forecasting ability, although this must await further testing of applications in the field for verification.

In terms of policy, the effects of incidents on transit ridership can be modeled quite accurately to determine temporal variations in the lingering effects of such incidents. The ability to measure past responses to incidents should help planners and decision makers in preparing for anticipated future shocks to transit performance, whether positive or negative in nature. It would be useful to know if the results reported here for incidents can be duplicated partially or wholly in other parts of the country, with similar or different types of transit markets in operation. A 1966 transit strike in New York City resulted in permanent regular ridership losses of only 2.1 percent for work trips, 2.6 percent for shopping trips, and 2.4 percent for all other trips, on the basis of an ex post travel behavior survey (*18*). Are the measured results for Orange County reported here much greater because of differences in sampling procedures, differences in modeling procedures, differences in the timing of work stoppage occurrence, differences in the spatial configuration of transit markets, or other factors? Additional study using data from multiple transit agencies might assist in answering some of these questions.

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Bay Area Emergency Ferry Service: Transportation Relief After the October 17, 1989, Earthquake

RICHARD M. FAHEY AND GEORGE E. GRAY

On October 17, 1989, the Loma Prieta earthquake of magnitude 7.1 disrupted the Bay Area's transportation system. Most noticeable, from a commuter's standpoint, was the loss of the use of the San Francisco-Oakland Bay Bridge (SFOBB). Emergency ferry service was developed immediately to provide transportation between San Francisco (in the West Bay) and Oakland, Alameda, Richmond, and Berkeley in the East Bay, all under one contract with the Red and White Fleet (owned by Crowley Maritime). This service lasted from October 23, 1989, through March 23, 1990. Caltrans also chartered three Washington State ferries to supplement the preexisting Vallejo-to-San Francisco service from October 30, 1989, to January 9, 1990. The Red and White Fleet also operated this service as subcharterer of the Washington vessels. Some of the problems that arose in operating the ferry service were the constant need to revise the different service contracts and ferry schedules, especially early on, as well as the uncertainty of Federal Emergency Management Agency reimbursement. Overall, however, the program was successful in providing an alternative commute mode for transbay travelers while the SFOBB was inoperative, and even after it was repaired. Evolving from the emergency service was the 1-year Oakland/Alameda-to-San Francisco ferry service pilot program as well as the development of a long-range plan for permanent Bay Area ferry service. The problems and successes of the emergency ferry service from start-up activities, through operations, to its present status are described. The main items of focus include ridership trends, operating costs and reimbursement, public sentiment, and legislation relating to the service.

The morning of Tuesday, October 17, 1989, saw a typical commute around the Bay Area. Those who lived in the East Bay and worked in or near San Francisco were commuting by one of the two available transbay modes: riding transit (Bay Area Rapid Transit or Alameda-Contra Costa Transit) or driving across one of three bridges linking East Bay to West Bay—mainly the San Francisco—Oakland Bay Bridge (SFOBB). Although there was no direct commuter ferry service connecting the East Bay to the West Bay at this time, there was ferry service serving various North Bay communities. Specifically, Golden Gate Transit ran daily commuter ferries from Larkspur and from Sausalito to San Francisco. Similarly, the Red and White Fleet operated ferry service from Vallejo and Tiburon to San Francisco.

Few, if any, of that morning's commuters were more concerned with how they would get home that night rather than with who would win that evening's scheduled third game of the World Series between (ironically) transbay rivals San Francisco Giants and Oakland As. Their attitudes all changed shortly after the 7.1 magnitude Loma Prieta earthquake struck the Bay Area that afternoon at 5:04 p.m.

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EMERGENCY FERRY SERVICE IN THE AFTERMATH OF THE EARTHQUAKE

Earthquake Damage Prompting Ferry Service

Although damage from the earthquake was extensive throughout the Bay Area and even in areas outside the Bay Area, some of the most comprehensive damage was sustained by the area's transportation system. First and foremost, a section of the SFOBB collapsed, rendering it unusable for at least 1 month. The SFOBB, which connects Oakland to San Francisco, was the main travel artery between the East and West Bay, handling an average of 243,000 vehicle-trips per day [Metropolitan Transportation Commission (MTC), unpublished data]. Now, all of the Bay Bridge commuters would be forced to find another way to get to and from work.

Another significant transportation problem created by the earthquake was the collapse of a 1-m section of the I-880 freeway, which was the main connector for people traveling from Oakland and areas south of Oakland, to the SFOBB. Closing of the I-880 freeway forced drivers to use either the already overcrowded I-580 connector, or to switch to riding BART using the Fremont line.

Other earthquake-related damage hampered travel between East Bay and West Bay because of the closures of many of the San Francisco freeways. The closures of I-480 (the Embarcadero freeway), I-280 from 101st to 6th St., the Fell St. on-ramp, and the 8th and 5th St. on-ramps to I-80 east, all made travel within San Francisco difficult. Even after the SFOBB reopened, most of these freeways and on-ramps remained closed, which continued to have an adverse effect on transbay travel.

Emergency Ferry Service

Start-Up Activities

On a typical day before the earthquake, the average number of peak-period (5 to 10 a.m.), westbound vehicle trips across the SFOBB was about 42,000 (MTC, unpublished data). The vehicle occupancy rate of westbound, morning peak-period

SFOBB commuters was about 1.42 (MTC/Caltrans, unpublished data). Thus, about 59,640 San Francisco-bound commuters had to find alternative means of crossing the bay for the next month. Unfortunately, what was left of the Bay Area's transportation system was ill-equipped to handle this extra load. It was decided that the best way not only to get commuters across the bay, but at the same time, to get them out of their automobiles, was to provide transbay ferry service until most of the damaged roadways could be repaired. Successful commuter and recreational ferry systems were already operating on the bay, and in recent years, transportation officials had seriously discussed providing commuter ferry service between East Bay and West Bay on a permanent basis.

On Thursday, October 19, a meeting with all the major transit service providers and selected public officials was held to discuss special emergency services. Each transit agency reported on the status of its operations and its ability to provide and add services. During the meeting, emergency ferry service between San Francisco and the East Bay was developed. Specifically, ferries would be run between the Ferry Building in San Francisco and four points in the East Bay: (a) Jack London Square in Oakland, (b) Todd Shipyards in Alameda, (c) the Container Terminal in Richmond, and (d) the Berkeley Marina in Berkeley. Also, plans were made to supplement the existing runs between Vallejo and San Francisco. Most of the East Bay transit services modified their schedules to accommodate the new, temporary, ferry terminals, and adjust to the closing of the SFOBB (see Figure 1).

In order to provide this additional service, more ferry boats would be needed. Therefore, Crowley Maritime (which owns and operates the Red and White Fleet) arranged to have four of its Catalina ferries from Southern California brought north to the Bay Area. Also, arrangements were made with the State of Washington's Department of Transportation to send down three of their vessels from Puget Sound, which were not being used at the time. The Washington ferries would primarily be used to supplement the Vallejo ferry service.

Contracts and Agreements

Once the basic ferry service was formulated, contracts and agreements between Caltrans and the ferry operators had to be drawn up. This process took place over the weekend of October 21, 1989, to get the service up and running by Monday, October 23. Three different agreements were drawn up to provide emergency ferry service. One agreement, RM–25, between Caltrans and Harbor Carriers required the Red and White Fleet (a subsidiary of Harbor Carriers) to provide ferry service between San Francisco and Richmond, Alameda, Oakland, and Berkeley. A second agreement, RM–26, executed between Caltrans and Harbor Carriers, was developed to supplement the already existing service between Vallejo and San Francisco with three extra vessels. However, Harbor Carriers did not own enough ferry boats both to supplement the Vallejo service and to operate the East Bay service. There-

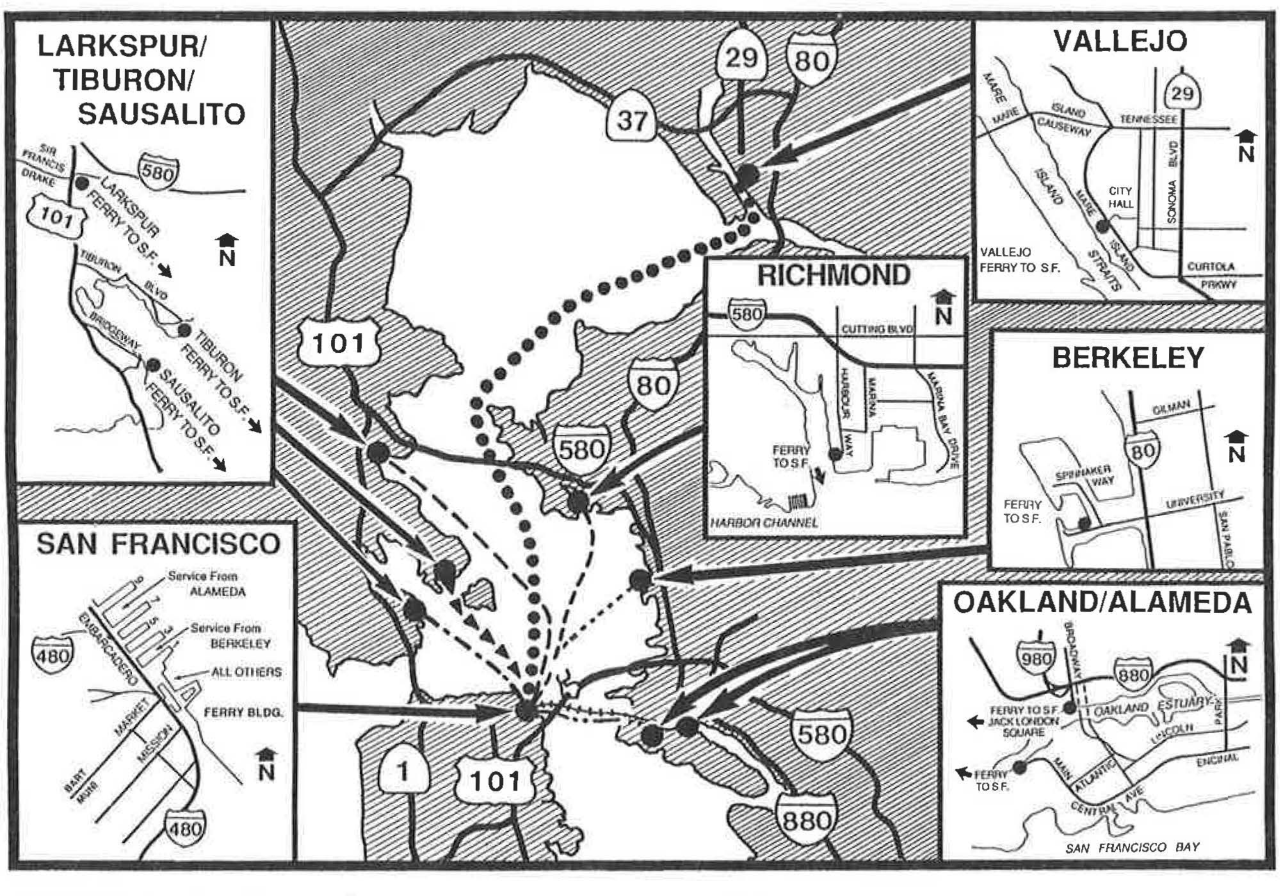


FIGURE 1 Bay Area ferry service map.

fore, a third agreement, the Bare-Boat Charter Agreement, between Caltrans and the State of Washington Department of Transportation, Marine Division, was executed, which named Caltrans as charterer of three Washington State vessels that were brought down to the Bay Area (*1*). Caltrans named Harbor Carriers as subcharterer to operate these ferries as part of the provision in RM–26.

Routes and Schedules

On Monday, October 23, less than 1 week after the earthquake, the emergency ferry service began operating with an aggressive schedule. The Oakland to San Francisco ferry left Oakland every 20 to 30 min beginning at 6:00 a.m. through midnight. The ferries returned on the same schedule. This made up 90 trips back and forth each day.

The Alameda ferry operated 12 runs per day on an hourly schedule only during the morning and evening peak periods. The Richmond ferry ran under an almost identical schedule also with 12 trips each day. The Vallejo ferry operated on a similar schedule with 10 runs per day, while the Berkeley ferry made 19 trips each way running hourly during peak periods and every 2 hr off-peak.

The Golden Gate Ferry Service catering to the North Bay also added extra runs to its already existing Larkspur and Sausalito ferry service to San Francisco. Figure 1 shows a map of the Bay Area with the various ferry routes as described. Throughout the entire 5 months of emergency ferry service operation, the schedule changed 17 different times. The majority of the changes, however, were minor—usually slight time changes in the routes for various reasons.

OPERATIONS HISTORY: OCTOBER 27, 1989, to MARCH 23, 1990

Ridership

Prequake Ferry Ridership

As mentioned earlier, of the emergency ferry routes just established, only the Vallejo to San Francisco service existed before the earthquake of October 17, 1989. The Red and White Fleet carried an average of 440 passengers per day between the two cities. Half of these daily passengers (220) rode the ferries during peak periods. In the aftermath of the earthquake, this service was supplemented through the use of the Washington State ferries.

Postquake Ferry Ridership

Although the daily ridership of the four East Bay ferries (Oakland, Alameda, Richmond, and Berkeley) varied greatly in total numbers, each system followed the same basic ridership pattern throughout the 5-month emergency program. From service initiation on October 23, 1989, the average daily ridership increased dramatically through mid-November, when the ridership figures peaked out and began to drop off. The reopening of the SFOBB on November 18 contributed to the steady decline in ferry patronage through December 22. On December 23, to use the emergency funding in a cost-effective manner, major service cuts were initiated that eliminated most weekend and midday ferry runs. This procedure produced a sharp reduction in daily ridership levels, although it did not noticeably affect peak-period ridership. From this point, the average daily ridership figures began to level off around mid-January, where they remained fairly constant through the end of service on March 23, 1990 (see Figure 2).

The Vallejo service showed similar ridership trends at first. As soon as the supplemental service started, the daily ridership increased sharply from the prequake levels of 440 riders per day. It also peaked out in mid-November and began to drop off after the reopening of the SFOBB. However, ridership figures here leveled off more quickly and averaged around 700 people per day through mid-December. From this point, the passenger counts began to drop off slightly each week through the end of state service on January 9, 1990. This dropoff was probably caused by the continuing uncertainty as to whether this service could be extended or canceled. The Vallejo service graph in Figure 2 shows the average daily ridership through March 23. Even though the ferry service there returned to prequake conditions after January 9, the ridership remained above its prequake average of 440 passengers per day.

Costs and Subsidy Analysis

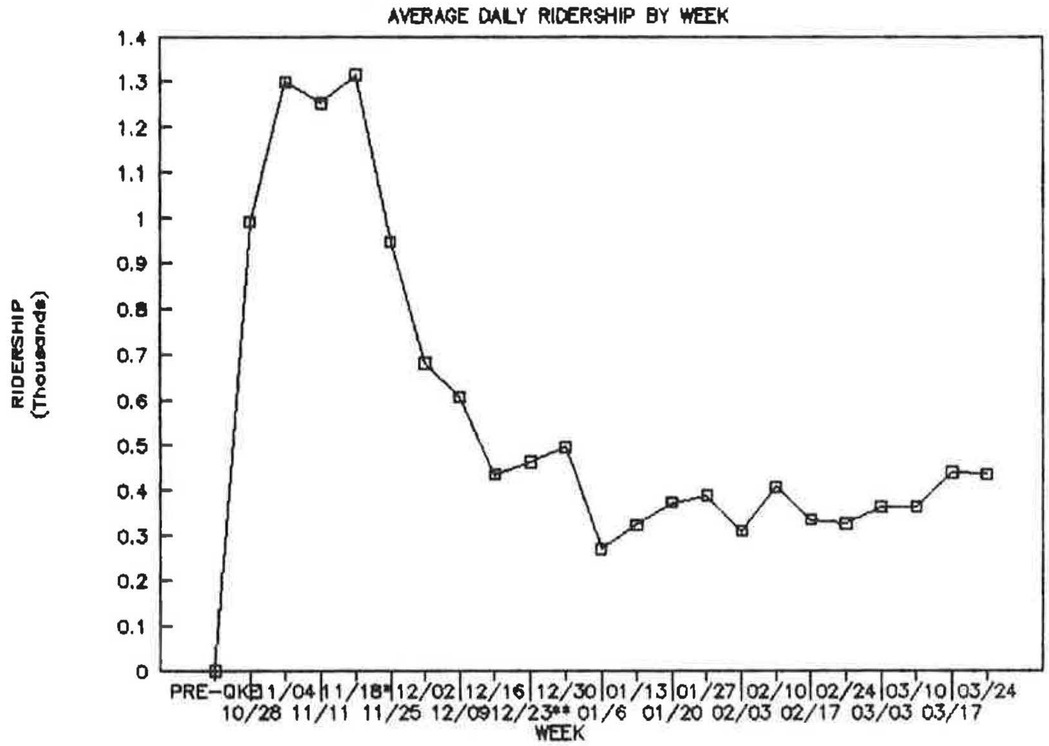
Even though some of the federal reimbursement funding for the ferry service was still in doubt, the majority of the costs involved in setting up and operating the emergency service had been identified. The total cost involved in operating the emergency ferry service from October 23, 1989, through March 23, 1990, was $6,450,578. These costs are presented in Table 1.

In the following section, the operating costs of the service are compared with the ridership figures at varying times during the 5-month operation. Table 2 presents the cost per passenger for both the Vallejo service and the East Bay service during the three different phases of the East Bay contract. The four East Bay routes are grouped into one category because Caltrans's contract with Crowley Maritime specified compensation for all four services in one fixed amount, rather than a separate cost for each service. The slightly higher cost per rider for the Vallejo service is most likely the result of higher operating costs caused by the longer trip lengths than those from the East Bay. The one-way trip length from Vallejo to San Francisco is 26.4 mi, whereas the average East Bay trip was 8 mi long.

The last column in Table 2 (subsidy per rider) is simply the difference between the operating cost of the service and the revenue credited to Caltrans, divided by the number of riders for that period. As expected, the cost per passenger increased as the ridership decreased throughout the service. In fact, near the end of the service period when the East Bay ridership was averaging about 1,000 people per day and Caltrans was paying Red and White Fleet $26,000 a day to operate, the cost per passenger was therefore $26.00—a primary reason for terminating the service.

The last row in Table 2 contains the total cost per passenger associated with the entire emergency ferry service operations.

(a)



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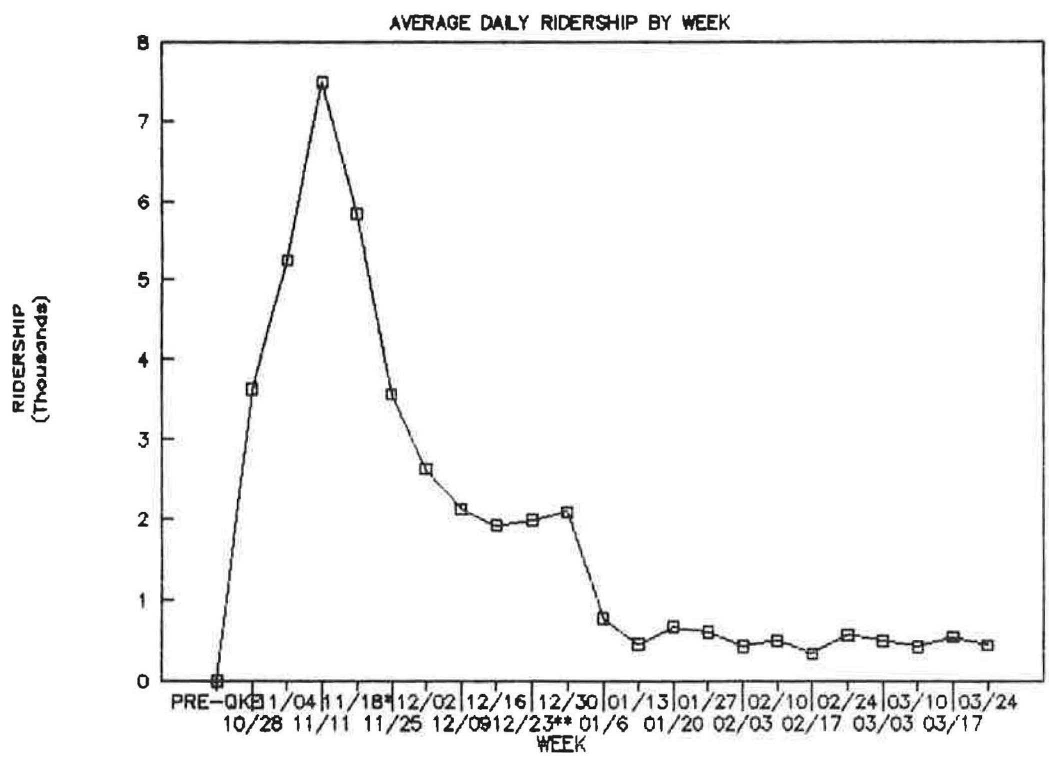
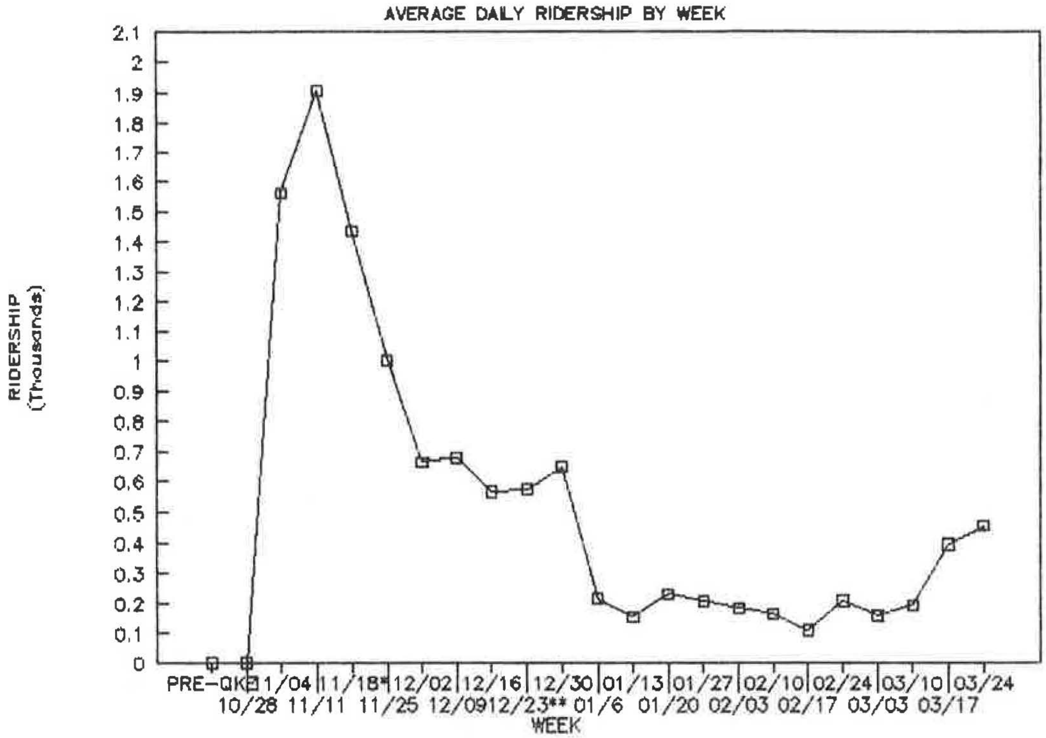


FIGURE 2 Ferry service ridership graphs for (a) Alameda, (b) Oakland, (c) Berkeley, (d) Richmond, (e) East Bay (total), and (f) Vallejo. ***(continued on next page)***

(c)



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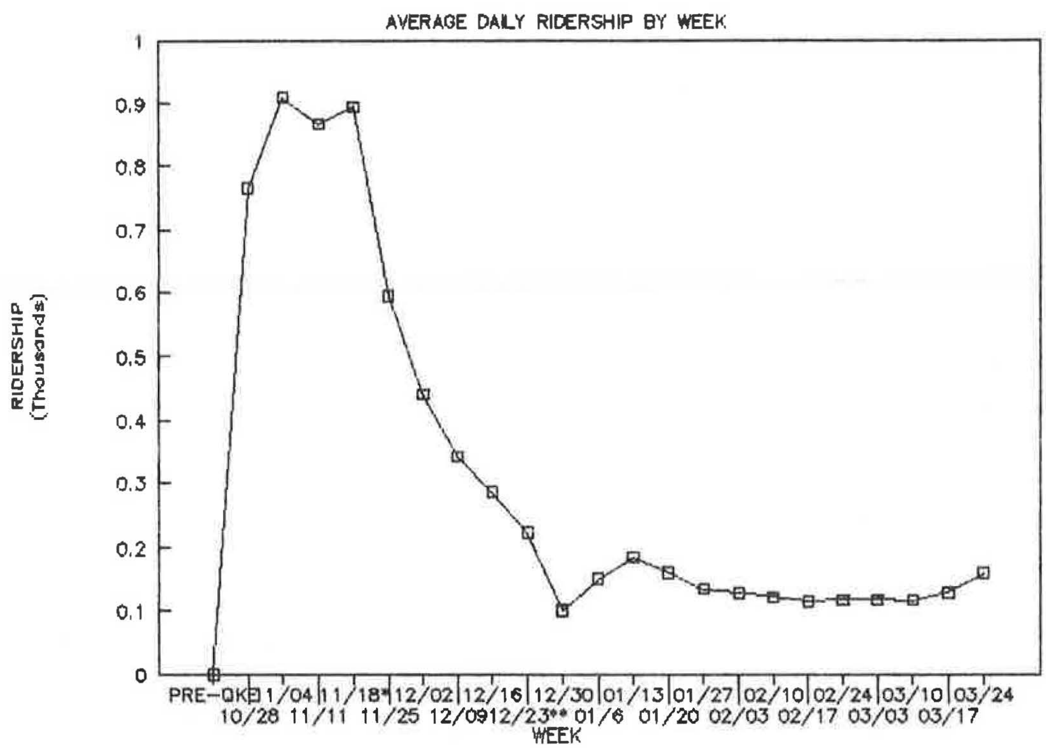
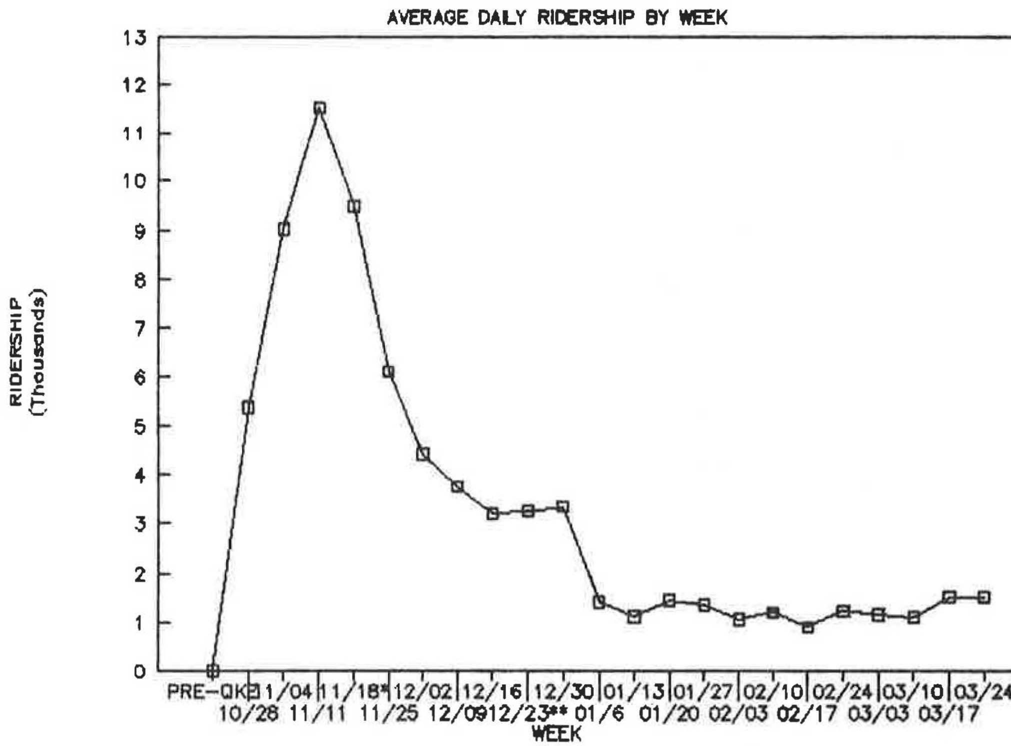


FIGURE 2 ***(Continued on next page)***

(e)



(f)

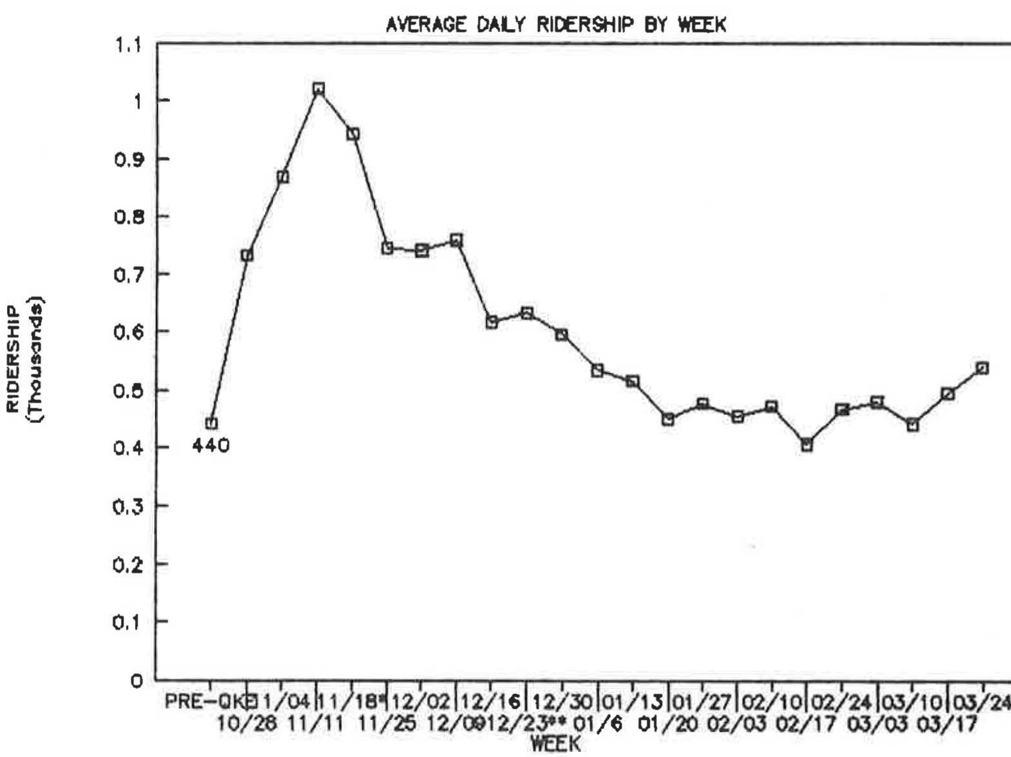


FIGURE 2 ***(Continued)***

TABLE 1 EMERGENCY FERRY SERVICE COST BREAKDOWN

Item	Cost
Ferry Boat Facility Investigation by Army Corps of Engineers.	$ 100,000
Ferry Boat Facility Dredging by Army Corps of Engineers.	$ 325,000
Ticket sales by toll collectors; Labor costs.	$ 222,082
Consultant Services.	$ 15,324
Parking lot & access road construction, and signage.	$ 145,946
Auditor Contract.	$ 2,787
Accounting services; ticket counting.	$ 11,436
Ticket printing.	$ 15,441
Caltrans staff; 10/26/89-1/25/90.	$ 20,300
Washington ferry boat charter, insurance, expenses, & repairs.	$ 384,718.11
East Bay Ferry Services; Total Operating Costs.	$4,466,555.50
Vallejo Ferry Service; Total Operating Costs.	$ 740,988.75
Total Emergency Ferry Service Costs:	$6,450,578.36

TABLE 2 ANALYSIS OF COST PER PASSENGER

Contract Period	Service	Operating Costs	Riders	Cost/ Rider	Caltrans Revenue	Subsidy/ Rider
10/23-11/17	East Bay	$1,239,556	234,341	$5.29	$651,735	$2.51
10/30-11/19	Vallejo	201,982	20,046	10.08	102,643	4.96
11/18-12/22	East Bay	1,615,000	144,265	11.19	133,920	10.27
11/20-12/24	Vallejo	371,402	23,340	15.91	126,993	10.47
12/23-3/23	East Bay	1,612,000	116,548	13.83	0	13.83
12/25-1/9	Vallejo	167,605	8,707	19.25	41,272	14.51
Total	East Bay	4,466,556	495,154	9.02	785,655	7.43
	Vallejo	740,989	52,093	14.22	270,908	9.02
Grand Total of All Services :		$6,450,578	547,247	$11.79	$1,056,563	$9.85

These amounts include all costs (operations plus dredging, ferry charter, ticket collection, etc.) and ridership figures for both the Vallejo and East Bay services. This indicates that the total cost per passenger was $11.79, or $9.85 per rider with State revenue subtracted from the cost.

Contract Amendments

Ferry Service Agreement RM–25

The following section discusses the different amendments to the three basic ferry contracts (RM–25, RM–26/Subcharter, and the Bare-Boat Charter Agreement) that occurred during the service period. As was mentioned earlier, the original service agreement RM–25 between Caltrans and Harbor Carriers, executed October 22, 1989, required Harbor Carriers to provide ferry service between San Francisco and three East Bay points: Richmond, Alameda, Oakland, and Berkeley. As compensation, Caltrans was to transmit all the revenue from $5.00 round-trip ticket sales to Harbor Carriers, plus $4.50 for each return-trip ticket collected. No contract termination date was identified, but instead, a 2-day cancellation notice by either party was required to terminate the agreement.

About 1 month later, Restatement and Amendment 1 modified the compensation clause so that Caltrans would reimburse Harbor Carriers $4.75 for each one-way ticket sold. The price per round-trip ticket was set at $5.00, with Caltrans to receive 100 percent of the revenue from ticket sales. Under this formula, Caltrans was providing a subsidy of $4.50 per passenger for each round-trip ticket sold. This payment schedule was only effective from October 23 through November 17, 1989. The revised contract also added a new compensation clause effective November 18 so that Caltrans would pay Harbor Carriers $47,500 per day of operation plus 60 percent of the revenue collected from ticket sales. It stated that the total payments from Caltrans to Harbor Carriers were not to exceed $2,765,000.

Also, under this restated contract, the agreement was to terminate on December 1, 1989, the date FHWA agreed to extend reimbursement for the emergency ferry service. With the passage of Senate Bill SB36X(89), which redirected $2,000,000 in Transit Capital Improvement funds to Caltrans to sustain the emergency ferry service, and the mounting public pressure to continue the program, the service was extended three different times during December (with Letters of Agreement) through December 29.

By this time, Caltrans was also in contact with the Federal Emergency Management Agency (FEMA) requesting its participation in reimbursement for ferry service costs. With the seemingly relative abundance in funding sources, and the outside pressure to continue the ferry service, a second amendment to the contract was executed that extended the ferry service through March 23, 1990, and increased the limit that Caltrans could pay Harbor Carriers to $4,000,000 (*2*). The compensation clause was also changed again to produce a simpler payment scheme. Under this amendment, effective December 22, Caltrans was to pay Harbor Carriers $26,000 per day to operate the East Bay ferry service. Also taking effect were major schedule changes (discussed in the next section) that eliminated most of the weekend and off-peak trips in order to stretch the subsidy as far as possible for peak-period users.

Service Agreement and Bare-Boat Subcharter RM–26

The other two contracts, the Bare-Boat charter and RM–26 subcharter, were interrelated. As was mentioned earlier, the RM–26 subcharter agreement between Caltrans and Crowley Maritime named Red and White Fleet as subcharterer of the Washington State vessels along with other provisions to supplement the Vallejo ferry service. Although this contract was never amended throughout the service period, it did contain some gray areas open to interpretation that required certain negotiating between the two parties afterwards.

First, the original compensation provision stated that Caltrans would reimburse Harbor Carriers its total costs plus an additional 10 percent of such costs, and that the two parties would meet, some time after the first week of service, to agree on a cost-plus-fixed-fee compensation amount. Months after the State's involvement in the Vallejo service had ended, and after continued negotiations, the following provision was agreed upon: "For the first week of service, Caltrans shall reimburse Harbor Carriers for the actual costs of conducting the Vallejo ferry service plus a fixed fee of $5,323.95," which was 10 percent of the first week's operating costs. The agreement also obligates Caltrans to pay a fixed fee of $6,191 per week for the remainder of the service period.

Another item in the subcharter section of the original contract needing revision was the insurance clause. The original insurance clause required Caltrans to add Harbor Carriers as additional insured to the hull and machinery insurance maintained by Caltrans and by Washington, when, in actuality, Harbor Carriers maintained its own insurance covering the Washington State vessels.

Finally, there was a question as to which party was responsible for specific repairs to the Washington State ferries. Even though the Red and White Fleet operated the vessels during the service period, Caltrans was ultimately responsible for the vessels. The contract language did not clarify matters either. It stated that "Harbor Carriers shall only be responsible (i) for ordinary maintenance and (ii) for repairing any damage Harbor Carriers may cause due to (their) failure to comply with Section VI of the Bare-Boat charter." Section VI requires the charterer not to operate the vessels at more than 25 knots nor more than 16 hours per day. Although Harbor Carriers appeared to stay within these boundaries while operating the Washington ferries, there was some minor damage to the boats, as well as some missing items.

The logical solution was to have Caltrans only pay for damages sustained during the trips between Seattle and San Francisco, while Crowley Maritime should be responsible for repair costs resulting from its operations. Unfortunately, the damages were not easily distinguishable because there was no on-hire survey done in Seattle, and the one done in San Francisco was hasty because of time constraints and the urgency of beginning emergency service. Therefore, the various repair costs were still being negotiated between the two parties, and the contract language regarding repairs was not yet amended.

Bare-Boat Charter Agreement

The Bare-Boat Charter Agreement between Caltrans and the State of Washington, as mentioned earlier, allowed Caltrans to use three Washington State ferries (which were subchartered to Crowley Maritime as described) at a rental rate of $18,300 per month, plus an additional charge of $2.00 per operating hour per engine. The original agreement was to expire on December 1, 1989. Caltrans was also responsible for the costs involved in transporting the vessels from Seattle to San Francisco and back again, including the off-hire survey inspection and repairs. The agreement also required Caltrans to provide insurance for the ferries from the time they left Seattle until the time they were returned.

On November 27, Supplement 1 to the Bare-Boat Charter Agreement was executed for two main reasons: (a) UMTA requested that the charter agreement include a federal interest clause as a condition of approval, and (b) Harbor Carriers requested a restatement of the hull and machinery insurance coverage in a format acceptable to its underwriters (*3*). Also, this supplement clarified that Caltrans would be responsible for the costs relating to travel and redelivery of the vessels.

Supplement 2, executed December 1, 1989, was simply an extension agreement to continue operating the service under the original charter agreement on a day-to-day basis (*4*). This choice was wise because it was still unclear at that point how long the ferry service would continue.

Table 3 presents the contract amendment and supplement information for the three main emergency ferry service contracts.

Schedules

Between the beginning of the emergency ferry services on October 23, 1989, and its last day, March 23, 1990, there had been 17 different schedules. Most of the schedule changes were minor, such as a slight time change to one of the five routes. Also, most of the schedule refinements took place within the first month or two of service. Other reasons or events prompting schedule changes included pier availability, citizen group requests, transit connections, and reductions in service to maximize the subsidy. Although these schedule changes did not have a noticeable impact on ridership, the early, continuous changes drew criticism from the public and the fluctuations and uncertainty may have scared off potential riders. At the same time, however, the schedule changes may have helped attract new riders who could not use the service under the previous schedules.

As ridership declined, certain ferry runs within various routes were eliminated in an effort to keep the service cost-effective. By mid-December, about 75 percent of the riders were using the service during peak hours. It was determined that by eliminating the weekend and off-peak runs, the State could save about $175,000 per week in operating costs, and therefore stretch the subsidy through mid-March. The most significant schedule change occurred on December 22, when most of the remaining midday and weekend runs were eliminated. The last schedule change occurred on February 17, 1990, and was used throughout the remainder of the service. Table 4 presents both the first schedule (full service), and the last (reduced service) for comparison.

TABLE 3 CONTRACT AMENDMENT SUMMARY

Original Contract	1st Amend/ Supplement	2nd Amend/ Supplement	3rd Amend/ Supplement
RM-25 (10/23-11/17) $4.75/ticket Revenue - CT	(11/18-12/22) $47,500/day Revenue Split: 60%-HC:40%-CT	(12/26-3/23) $26,000/day Revenue - HC	(2/23/90) $4,852,635 pay cap
RM-26 (10/30-1/9) Cost plus 10% fixed fee.	(Unsigned) 1st week's costs + 10%. Op. Costs + $6191/week. Modified insurance clause.		
BAREBOAT (10/30-12/1) Charter three WA ferries.	(11/27/89) Federal clause. Ins. modification. Redelivery costs.	(12/1/89) Charter extension: Day by day agreement.	

CT = Caltrans
HC = Harbor Carriers

TABLE 4 COMPARISON OF SCHEDULE 1 AND SCHEDULE 7

SCHEDULE #1	SCHEDULE #17
From Oakland to S.F. Ferry Building. (40 minutes)	
- Leave at 6 a.m. and every 20-30 minutes thereafter until midnight.	- Leave at 6 a.m. and every hour thereafter until 10:00 p.m.
- Ferries return on same schedule.	- Ferries return on same schedule.
From Alameda to S.F. Ferry Building. (35 minutes)	
- Leave 6,7,8,9 a.m. and 5,6 p.m.	- Leave hourly from 6:15-10:15 a.m. and every other hour until 4:45 p.m., then hourly until 8:15 p.m.
- Return 7,8 a.m. and 4,5,6,7 p.m.	- Return on similar schedule.
From Richmond to San Francisco Pier 9. (45 minutes)	
- Leave 6,7,8,9 a.m. / 5:30, 6:30 p.m.	- Leave 6,7,8 a.m. / 5:25 p.m.
- Return 7,8 a.m. / 4:30, 5:30, 6:30, 7:30 p.m.	- Return 6:50 a.m./4:30,5:30,6:30 p.m.
From Berkeley to San Francisco Pier 3. (Beginning 10/30/89) (40 minutes)	
- Leave at 6:00 a.m. and every hour (two hours, mid-day) until 8:00 p.m.	- Leave at 6:00 a.m. and every other hour until 8:30 p.m.
- Return at 7:00 a.m. and every hour (two hours, mid-day) until 7:00 p.m.	- Return on similar schedule.
From Vallejo to S.F. Ferry Building. (60 minutes)	
- Ferries leave 6:00 and 6:30 a.m.	- Subsidized service ended 1/9/90.
- Return at 5:15, 6:15, and 7:40 p.m.	

Reimbursement Funding

As was mentioned at the outset, emergency relief funding to operate the ferry service while the SFOBB was being repaired was secured from the FHWA. Eventually, Caltrans received a funding extension from the FHWA through December 1, 1989. By this time, it was estimated Caltrans had spent $1,635,997 in operating the emergency service, which was reimbursed by the FHWA. Also by this time, an extra $2,000,000 had become available to extend ferry operations with the passage of Senate Bill SBX36(89).

During this time, Caltrans was submitting damage survey reports (DSRs) to FEMA as part of the process for receiving reimbursement for the costs of all repairs and services made necessary by the earthquake. All requests for federal aid were made through the state Office of Emergency Services (OES), which would request FEMA participation on the basis of Caltrans's requests. It was originally understood that FEMA would reimburse Caltrans from the time FHWA funding stopped (December 1, 1989) through a period when traffic patterns on and around the SFOBB returned to normal. It was difficult to predict when this might happen, but by canceling most midday and weekend ferry runs, and eliminating the Vallejo subsidized service (on January 9, 1990), it was determined that the East Bay service could be maintained through mid-March of 1990 by using the available funding.

Unfortunately, Caltrans did not learn until January 9, 1990, that FEMA had planned to terminate financial assistance on

December 31, 1989. In spite of this, Caltrans decided to stick to its original plan of operating the service through March by using SBX36(89) funds and, at the same time, to appeal FEMA's December 31, 1989, cut-off date. In mid-April (3 weeks after ferry service termination), Caltrans learned that FEMA had rejected the appeal, prompting a second-level appeal to be submitted. Two weeks later, it was learned that FEMA had decided not to participate in any ferry service-related funding at all. This decision prompted a meeting between Caltrans, FEMA, and OES to resolve matters. FEMA officials indicated they would consider reimbursement for the service for as long as ridership warranted running such service. Caltrans submitted a supplement to the second appeal that specifically pointed out that FEMA should provide financial aid for the ferry service at least through February 9, the approximate date that SFOBB traffic volumes began to return to normal levels (B. Crockett, unpublished data).

Outstanding service costs to Caltrans during this period totaled $2,910,555. With Caltrans providing a 25 percent FEMA match [using SBX36(89) funds], the total amount Caltrans requested from FEMA was $2,182,916. Table 5 presents the entire financial spreadsheet, including costs and funding sources for the emergency ferry service.

To date, Caltrans has not received a response from FEMA either accepting or rejecting the second appeal. Therefore, Table 6 presents the breakdown of the two possible reimbursement scenarios: (a) FEMA provides financial aid through February 9, 1990, and (b) FEMA provides no aid for ferry service. The first scenario would leave Caltrans with a balance of $518,362 in SBX36(89) funds, which would be returned to the state legislature; whereas the second leaves Caltrans with a deficit of $1,664,553. The Caltrans cost figure of $5,947,632 refers to the total net costs, derived from all costs less revenue and other credits.

Figure 3 shows a proportional breakdown of the net costs and reimbursement sources involved. The 3.7 percent contributed by Caltrans under the reimbursement breakdown chart reflects the labor costs of the toll collectors who sold and collected ferry tickets while the SFOBB was inoperative. The 7.1 percent reimbursed by the Army Corps of Engineers was for their postquake port investigations and Berkeley channel dredging related to the ferry service.

Public Sentiment

Although ferry ridership began to subside after the SFOBB reopened, the amount of public support for the ferries, and for continued ferry service did just the opposite. The more the State threatened to eliminate the ferry service because of decreasing ridership, the more letters that were received by Caltrans and the legislators from angry support groups and individuals. For example, Caltrans received many letters from commuters riding the Vallejo ferries when they learned that Caltrans planned to terminate the supplemental service. One ferry support group, The Berkeley Ferry Committee, submitted a letter with over 2,300 signatures, and approximately 150 separate letters, to the Caltrans district director requesting that the State keep the Berkeley ferry service operating on a permanent, subsidized basis. Similarly, many East Bay politicians were the recipients of letters from their constituents who wanted to see the Oakland and Alameda ferries kept running on a permanent basis.

As it turned out, perhaps partly because of public pressure, the Oakland and Alameda ferry service was continued, after State involvement ceased, by the City of Alameda and the Port of Oakland as a 1-year demonstration project. Some of the different ferry support groups that were formed included the following: The Berkeley Ferry Committee, The Richmond Ferry Run, The North Bay Water Commuters out of Vallejo, The Tiburon Commuters from Marin County, and The Bay Organization for Aquatic Transit (B.O.A.T.). The latter was originally formed to support the Oakland and Alameda ferry runs, but eventually reorganized to include representatives of all the other support groups to create an alliance to help facilitate the development of a Bay Area ferry system. These groups were all successful in recruiting volunteers, distributing schedules and informational newsletters, and keeping local politicians informed of their concerns.

Legislation

Many measures were passed during the 5-month period that affected the emergency ferry service—most of which were authored by Senator Quentin Kopp (San Francisco), or Senator Keene (Vallejo). Most of the State bills passed during this time provided funds or authorization for earthquake damage relief of all types, not strictly ferry service activities. The following section, however, describes how the different measures related specifically to the ferry service.

Immediately after the earthquake, the governor declared a state of emergency. This allowed the quick implementation of the emergency ferry service. Many of the approvals and regulations that would normally apply to ferry operation on the bay were now superseded under the state of emergency. This situation enabled dredging, parking lot construction, and service contract negotiations.

A few weeks later, on November 2, Senator Keene introduced Senate Bill SBX37, which required the MTC to develop a permanent ferry plan for the San Francisco Bay and the City of Vallejo to determine the feasibility of acquiring ferries on a permanent basis. Two days later, Senator Kopp introduced Senate Bill SBX36 (adopted November 7, 1989), which, among other things, transferred $2,000,000 from Transit Capital Improvement funds to Caltrans to sustain emergency ferry services. It also reallocated $1,500,000 from the same funding source to MTC for allocation to transit operators for continuation of their emergency bus and rail services.

Senate Bill SBX39 by Senator Kopp, introduced on January 23, required the MTC to develop objective criteria (including ridership per run, fare box recovery ratio, and local financial support), to determine which ferry runs were the most cost-effective so that the limited funding could be used efficiently. Although this bill was not adopted until July 7, 1990, these criteria (among others) were being used all along by the State in an effort to stretch the limited funding by eliminating the least cost-effective runs, such as the midday and weekend service.

Senate Bill SBX2169, adopted at the beginning of 1990, authorized MTC to develop and adopt a long-range plan for implementing high-speed water transit on the San Francisco

TABLE 5 EMERGENCY FERRY SERVICE REIMBURSEMENT AND EXPENDITURE REPORT

Item	R&W Contract Payments ($)	Total Costs ($)	FHWA ($)	FEMA ($)	Caltrans ($)	Army Corps ($)	SBX36 Funding ($)	MTC/ Vallejo ($)	Revenue ($) Kept by R&W	Revenue ($) Credited to Caltrans	Revenue ($) Total
COE investigation		100,000				100,000					
COE dredging		325,000				325,000					
Toll collectors		222,082			222,082						
Consultants		15,324	15,324								
Parking/access/signs		145,946	145,946								
Auditor contract		2,787	2,787								
Accounting/Tickets counting		11,436		11,436							
Ticket printing		15,441	7,000	8,441							
Caltrans staff 10/26–1/25		20,300		20,300							
Operating costs											
Washington DOT											
Insurance		73,981	73,981								
Monthly fees ($18,300/mo)		62,220	19,520								
Engine hours ($2/op-hr/eng.)		18,608	3,960								
Expenses (labor, travel, etc.)		142,555	129,000								
Off hire/drydocking/ Props.		18,869	60,000								
Repairs (R&W responsible)		68,486									
Subtotal		384,718	286,461	98,258							
East Bay											
10/23–11/05[a] (14 days)	596,330	596,330							0	313,195	313,195
11/6–11/17 (12 days)	643,226	643,226	487,815						0	338,540	338,540
11/18–12/1[b] (13 days)	558,922	617,500	590,500						87,867	58,578	146,445
12/2–12/15 (14 days)	610,976	665,000							81,036	54,024	135,060
12/16–12/22 (7 days)	311,182	332,500							31,977	21,318	53,295
12/26–3/23/90[c] (62 days)	1,612,000	1,612,000							558,000	0	558,000[e]
Subtotal (122 days)	4,332,636	4,466,556	1,078,315	2,500,321[d]			753,999		758,880	785,655	1,544,535[e]
Operating costs + fixed fee, Vallejo											
10/30–1/9[f] (70 days)	371,962	740,989	100,164	271,799				98,118	270,908	270,908	270,908
Total	4,704,598	6,450,578	1,635,997	2,182,916[g]	222,082	425,000	1,481,638[h]	98,118	1,029,788	1,056,564	1,815,444
$ 2 mil balance							518,362				

NOTE: Assumes FHWA reimbursement, 10/30–12/1; FEMA reimbursement, 10/30–2/09. Total Payments to R&W, sum of Columns 1 and 9: $4,704,598 + $1,029,788 = $5,734,386.

[a]10/23–11/17: Payments to R&W = no. of tickets sold × $4.75. CT keeps 100 percent of revenue (revenue = $651,735.32).

[b]11/18–12/22: Payments to R&W = $47,500/day + 60 percent revenue. CT keeps 40 percent of revenue (revenue = $334,800).

[c]12/26–3/23: Payments to R&W = $26,000/day + 100 percent revenue. (Reduced service, not on weekends).

[d]Through 2/9/90.

[e]Revenue estimation: = 1800RT/Day * $5 * days)

[f]Vallejo 10/30–1/9: Payments to R&W = op. costs + fixed fee ($6191/wk). Weekend service throughout.

[g]Less $727,639 FEMA 25 percent match from SBX36.

[h]Plus $727,639 FEMA 25 percent match from SBX36.

TABLE 6 REIMBURSEMENT SOURCES

	(1) FEMA Aid	(2) No FEMA Aid
SOURCE	AMOUNT	AMOUNT
FEMA	$2,182,916	$ 0
FHWA	$1,635,997	$1,635,997
CALTRANS	$ 222,082	$ 222,082
ARMY CORPS	$ 425,000	$ 425,000
25% FEMA MATCH	$ 727,639	
SBX36 FUNDS	$ 753,998	$2,000,000
TOTAL REIMB.:	$5,947,632	$4,283,079
CALTRANS COSTS:	$5,947,632	$5,947,632
SURPLUS SBX36:	$ 518,362	$ 0
DEFICIT:	$ 0	$1,664,553

(a)

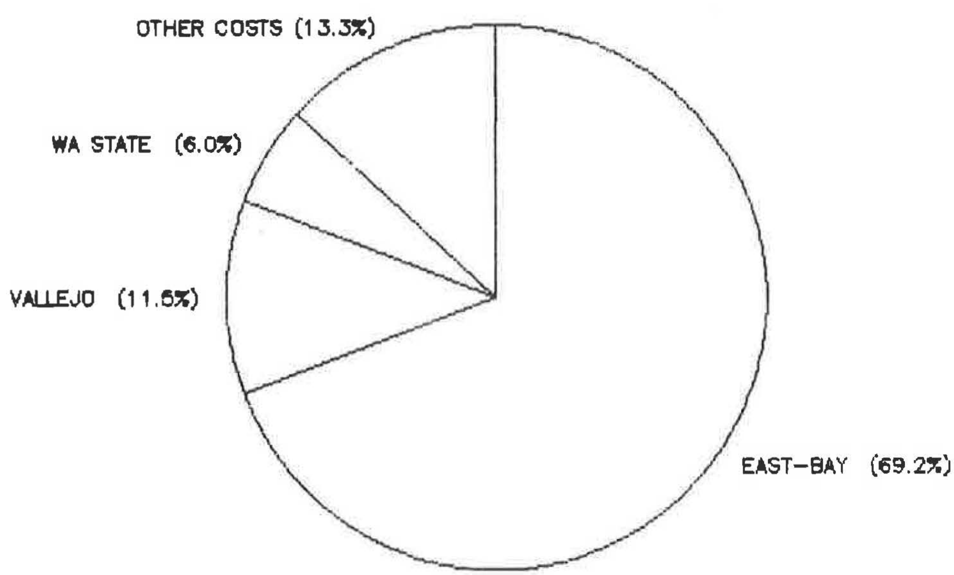


FIGURE 3 Breakdown of funds: (a) costs (total $5,947,632) and (b) reimbursements (total $5,947,632).
(continued on next page)

(b)

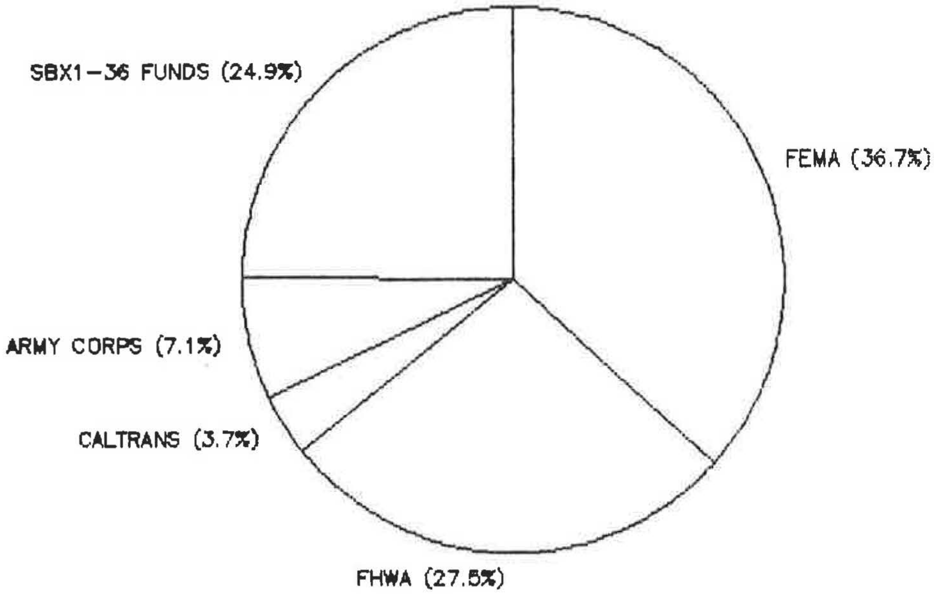


FIGURE 3 *(continued)*

Bay. By this point, the emergency service was winding down, so this bill was introduced to help develop a more permanent transbay ferry service.

Finally, Proposition 116 on the California ballot was passed by voters in the June election. Although this proposition had no effect on the emergency ferry service, it will provide $30,000,000 for waterborne ferry systems through bonds. Specifically, it provides $10,000,000 to the City of Vallejo for capital improvements to the Vallejo ferry service. It also allocates $20,000,000 to local agencies through competitive (state-wide) grants for construction, improvements, acquisition and other capital expenditures for ferry service.

OVERVIEW

Although problems were encountered throughout its operation, the emergency ferry service successfully transported thousands of people across the San Francisco Bay on a daily basis.

Two obvious problems encountered during the 5-month period of emergency service were (a) the constant contract revisions required and (b) the continually changing ferry schedules. Considering the circumstances, however, these were minor complications. The original contracts were developed and executed quickly to implement service as soon as possible. Most of the eventual factors that necessitated contract revisions, such as additional funding sources, ridership levels, insurance needs, public pressure, etc. could not have been foreseen when the contracts were first developed. In hindsight, the contract with the fewest problems was the simplest: RM–25, Amendment 2, which required Caltrans to pay a fixed daily fee of $26,000 for the East Bay ferry service. Of course, this fee was developed after the funding sources had been identified and the operation duration specified.

Another problem, which still exists, is the indecision by FEMA as to whether they will reimburse Caltrans for some or any of the costs in operating the ferry service. It is not known if this dilemma could have been avoided.

On the positive side, there was tremendous and unprecedented cooperation between the local transit operators, federal, state, and local officials, local politicians, and the private sector in developing and operating an alternative public transportation system on such short notice. Also on the plus side, the emergency ferry service carried over 547,000 passengers over the 5-month period, and averaged over 4,200 trips per day. Another benefit to emerge from this situation was the long-range plan to provide transbay ferry service, which MTC is now developing. Finally, one of the most important secondary developments is that the City of Alameda, the Port of Oakland, and MTC are now jointly subsidizing a 1-year trial ferry service program between Oakland, Alameda, and San Francisco, which is simply a continuation of the emergency ferry service. If successful, it will become a permanent fixture on the Bay.

Unfortunately, however, it took a major earthquake to create the temporary transbay ferry service, and to prove to many people that there are viable alternatives to the automobile.

REFERENCES

1. *Bare-Boat Charter Agreement Between Washington State Department of Transportation Marine Division and California Department of Transportation.* Oct. 20, 1989, p. 15.
2. *San Francisco Bay Purchase of Ferry Service Agreement RM–25, Amendment 2.* Dec. 22, 1989, pp. 6–7.
3. *Bare-Boat Charter Agreement, Supplement No. 1.* Nov. 27, 1989, pp. 1,3.
4. Bare-Boat Charter Agreement, Supplement No. 2. Dec. 1, 1989, p. 2.

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