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Foreword

The 10 papers in this Record represent a good cross section of the transit administration and planning issues that face public transportation agencies. The diversity of the topics demonstrates the wide range of transit problems in need of research. Seven papers can be categorized in the general area of transit planning, and the three remaining papers consider transit administration.

Two papers explore ways of encouraging transit and ridesharing through transportation system demand-management strategies. DeCorla-Souza and Gupta report on a study that evaluated incentive programs implemented elsewhere in North America. The results indicate that an effective and cost-efficient way to relieve future congestion would be encouragement of both transit and ridesharing on a systemwide basis through a high-frequency, multicentered, pulsing scheduled transit system; a system of high-occupancy vehicle lanes; and automobile pricing. Najafi and Nassar present a quick response approach to evaluate two types of transportation investments, namely adding lanes to an existing highway or providing an express bus service. Delay, which is used as the sole evaluation measure, is suggested as the most treasured commodity and is therefore a good measure of effectiveness of the alternatives under consideration.

Bettger and Pearson describe their study of the types of problems experienced by hearing-impaired people using public transportation systems in Massachusetts. The limited oral communication abilities of the hearing impaired result in missed connections and increased risk in emergencies during travel by bus and subways and at airports. Recommendations for regulatory changes and specific designs that can be applied to public bus, rail, and air transportation systems are given.

Three papers consider transit operations planning. Miller and Crowley present the results of a pilot panel survey procedure to determine transit service elasticities of demand under a range of operating and demographic conditions. A randomly selected panel of potential transit users was surveyed before and after a transit service change, and their observed transit use became input for determining service elasticity characteristics. In the second operations planning paper, by Foerster and Imlay, eight models for predicting ridership levels on new transit routes on the basis of early performance are compared. Results indicate that forecasts based on less than 6 months of data are unreliable and that simple manual methods based on prior experience with other local routes are more effective if ridership forecasts must be produced from limited amounts of data. In the third paper, Peter Furth presents a procedure for estimating ride checks (ons and offs by stop) by updating ride checks with recent multiple point check data (on, off, and load at selected points). Testing demonstrates how estimation accuracy varies with number of points checked, number of days checked, and length of time period of aggregation. Trip-level estimates were unreliable, but period-level estimates were found to have good accuracy.

Zimmerman presents a number of case studies to illustrate UMTA's major investment rating process. Two groups of projects, those that are highly rated as potential federal transit investments and those that do not fare well, are compared. The highly rated projects were generally found to be critical pieces of much larger systems, so that a modest investment could produce tremendous benefits. The poorly rated projects are unable to generate significant new transit ridership, despite large investments, and are affected by the precarious condition of transit finances in their communities.

The first of the three papers covering transit management issues treats the subject of labor. Barnum identifies the labor requirements, applicable when transportation organizations increase competition through subcontracting or service contracting and suggests methods for meeting those labor requirements. Foote and Hancox examine how the Chicago Transit Authority is meeting the challenge of collecting Section 15 data. Their method of determining annual unlinked trips and passenger-miles for the bus and rail system and their stratified rail sampling plan are presented.

The last paper describes a targeted marketing program that was used in Portland, Oregon. In connection with the opening of a light rail line, several bus routes were altered to provide feeder bus service to rail stations. A direct mail campaign was designed to increase feeder bus ridership, with mixed results. The greatest response came from those who already rode transit, and ridership on the feeder buses increased slightly. It was determined that the demographics of an area should be evaluated at the beginning of promotional efforts so that the marketing program could be tailored to site-specific characteristics.

Evaluation of Demand-Management Strategies for Toledo's Year 2010 Transportation Plan

PATRICK DECORLA-SOUZA AND JIWAN D. GUPTA

This paper attempts to evaluate transportation system demand-management strategies—specifically, strategies to encourage transit and ridesharing—as a long-range solution to systemwide traffic congestion problems in the Toledo metropolitan area. The Toledo Metropolitan Area Council of Governments (TMACOG) has forecasted that there will be severe congestion on major arterials and on the freeway and expressway system by the year 2010, and financial resources to address the problem will be limited. Innovative transit system designs, auto pricing, and ridesharing incentives that have been implemented elsewhere in North America were investigated. Their applicability to the Toledo area was reviewed, and synergistic combinations of specific policies were developed for testing with computerized travel models. The results indicated that the most effective and economically efficient way to relieve forecasted congestion would be a policy that encourages both transit and ridesharing on a systemwide basis—through a high-frequency, multicentered, pulsing-scheduled transit system; a system of high-occupancy vehicle lanes; and use of auto pricing. The results of the evaluation also indicated that a combined transit/ridesharing-preferential strategy compares favorably with other strategies with respect to other objectives of TMACOG's long-range transportation plan—transit viability, economic development, safety, and maximization of social and environmental benefits. The study made a useful contribution in assisting TMACOG's Long Range Plan Task Force in the development of transit and ridesharing policies for its Year 2010 Transportation Plan.

Highway systems in most urban areas in the United States are in the "developed" stage. Also, financial resources available for construction of new or expanded highway facilities are meager, and right-of-way for accommodation of such facilities is scarce. It is anticipated that few new facilities will be built in the future.

Urban traffic congestion, however, continues to increase as a result of continuing urban sprawl and increasing dependence on the private vehicle for urban transportation. It is clear that traditional methods for solving urban congestion problems, which are primarily oriented toward improving highway system "supply" characteristics, will have limited applicability in the development of transportation systems to serve urban travel demand beyond the year 2000. Failure to maintain urban mobility in a cost-efficient manner could lead to degradation of urban lifestyles and regional economies.

As planners of the urban transportation system in the Toledo urban area began the process for development of a transportation plan for the year 2010, it was clear to them that they must broaden their search for long-range solutions to forecasted traffic-congestion problems. Greater emphasis would have to be placed on development of innovative strategies to increase the person-carrying capacity of the existing highway system. At the same time, the strategies would have to address the need to conserve energy and economic resources, preserve environmental quality and neighborhoods, and serve the mobility needs of an aging population.

As the Long Range Plan Task Force of the Toledo Metropolitan Area Council of Governments (TMACOG) proceeded to develop alternative transportation plans for computer testing and evaluation, the limits of financial capability for highway capital spending had already been recognized (*1*). Several potential system-oriented solutions related to travel demand management—particularly encouragement of transit and ridesharing—had been proposed at a "Charrette" (*2*). The Charrette was an intensive brainstorming session that brought together more than 100 key community leaders, transportation system users and providers, and government officials over a 24-hr period. Its purpose was to seek a consensus on solutions to transportation problems over the next 20 years. Solutions suggested at the Charrette included auto parking and pricing policies, a high-speed multicentered transit system with high levels of collection and distribution service to and from transit centers, and policies and systems to encourage ridesharing among commuters.

PURPOSE OF STUDY

The Long Range Plan Task Force sought information to help in evaluating the travel demand-management strategies proposed at the Charrette. Information was sought on the relative impacts of the strategies if they were to be implemented in the Toledo area. This study was undertaken to evaluate the relative merits of alternative strategies on a systemwide basis using TMACOG's computerized travel models to estimate travel impacts.

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STUDY PROCEDURE

The study procedure involved the following steps:

1. A review of the literature to become familiar with current knowledge and practice related to travel demand management and formulate strategies applicable in the Toledo area.
2. An evaluation of the severity of peak-period traffic congestion forecasted by TMACOG through the year 2010.
3. Formulation of alternative demand-management strategies to address forecasted peak-period traffic congestion problems.
4. Computer simulation of peak-period traffic on the highway system under each strategy to evaluate the impacts on peak period traffic congestion in 2010.
5. Analysis and evaluation of the alternative strategies, with special emphasis on their economic efficiency and ability to relieve forecasted peak-period traffic congestion.

LITERATURE REVIEW

A discussion of the insights gleaned from the literature review is presented in two parts: (a) modal strategies [transit and high-occupancy vehicles (HOVs)] and (b) pricing strategies (parking and road pricing).

Modal Strategies

Belobaba (*3*) has described a rapid transit bus system planned for the Ottawa, Canada, urban area. The area had a 1978 population of about 525,000, approximately the size of the Toledo area. The study concluded that a transportation policy that did not include transit operations on priority rights-of-way "would leave the transit system at the mercy of increased road congestion, resulting in lower operating speeds and, therefore, significantly higher operating costs." A rapid bus system was preferred over light rail because of the greater overall economic efficiency of a rapid bus system and the flexibility of buses to leave the rapid-transit right-of-way to provide same-vehicle line haul and feeder service. Bonsall (*4*) has indicated that Ottawa's busway system and supporting transit improvements have been an unqualified success—over 30 percent of all person-trips in the region and 60 percent of all downtown-destined peak-hour journeys were being made by public transit in 1985.

Fisher (*5*) concluded that a substantial change in the mode choice of commuters resulted from the opening of the full length of exclusive roadway for HOVs in the median of the Shirley Highway (in the Washington, D.C. area) and the initiation of eight new express bus routes. In remarks presented at the 65th Annual Meeting of the Transportation Research Board in January 1986, R. G. Sarros reported that at that time 70 percent of the persons moved inbound in the weekday a.m. rush period were transported in multioccupant vehicles on the two inbound HOV lanes, whereas only 30 percent were transported on the three inbound unrestricted lanes. When a transitway was built in the median of the six-lane Katy Freeway in Houston, Texas, over 40 percent of the total peak-hour, peak-direction person movement was taking place in the transitway (*6*). Capelle et al. (*7*) have indicated the advantages of a bus/HOV facility system: increase in freeway efficiency, reduced subsidies for transit, amenability to phasing over time, implementability in concert with freeway rehabilitation or other highway improvement projects, and an increase in the availability of federal funding because both highway and transit funding are available. Toledo has a unique opportunity to incorporate bus/HOV facility studies into its Interstate Highway Needs Study (*8*) scheduled to begin soon.

Nakadegawa (*9*, p. 1 and 9) and Schneider et al. (*10*) have presented transit system design concepts that can relieve traffic congestion not only in urban core areas but also in suburbia. Nakadegawa has proposed a multicentered timed-transfer system with frequent and swift bus service via exclusive busways that link employment and shopping centers with residential neighborhoods. Schneider et al. indicate that a timed-transfer or "pulsing-scheduled" transit system has enabled Edmonton, Canada, to serve both cross-town and radial commuting patterns. Travel times dropped by about 20 percent under the timed-transfer arrangement (*11*).

Priest and Walsh-Russo (*12*) have shown that although the decentralization trend in many metropolitan areas is well advanced, new trends are emerging that favor clustering of offices, some retail, and residential uses. Where transit has adapted to the multinucleated urban pattern, sustained ridership growth has been achieved. In Ottawa, Canada, a by-product of the transitway system has been the clustering of high-rise apartments around several outlying stations (*13*). In Edmonton, Canada, shopping malls reported significant gains in sales following the opening of on-site transit centers, whereas competing retail centers without a transit facility were experiencing losses (*14*). These experiences indicate that coordination of transit and land development policies in the suburbs can result in both mobility and economic benefits.

Pricing Strategies

Future travel demand can also be modified by disincentives to the inefficient use of single-occupant automobiles for work travel. Shoup (*15*) has shown that free employee parking rewards solo drivers. Letting employers pay their employees tax-exempt cash instead of giving them tax-exempt free parking, would eliminate free parking's almost irresistible invitation to drive alone to work, and use of transit and carpooling would increase. Fitch (*16*, pp. 122–146, 265–266) has indicated that if peak period motorists were to pay the full cost of their use of resources, the prices paid by them would be vastly greater. Highways are designed for peak-hour use, with extra lanes, ramps, and traffic control devices that would not be needed for the smaller volumes of off-peak traffic. But the cost of using the facility during the peak hour consists only of gasoline taxes, which are paid uniformly by peak and off-peak users. Failure to confront peak-hour motorists with the true cost of highway use encourages them to use a means of transportation with high resource costs. A well-documented example of road pricing is the Singapore area license plan (*17*). A license requirement was instituted for vehicles entering a core-area zone between 7:30 a.m. and 10:15 a.m., and a 100 percent increase in parking charges at public lots within the zone was instituted. As a result, the number of cars entering the zone in the a.m. peak period fell by 73 percent, and carpooling increased by 60 percent.

Road pricing is an effective and efficient way to reduce traffic volumes when and where they create problems of congestion. Unlike fuel taxes, the charges can be easily adjusted by time, location, and degree. Unlike parking taxes, they can affect inbound trips as well as trips going through the congested area. In the late 1970s, UMTA initiated a demonstration program to pay for implementation of the license approach (similar to Singapore's) in U.S. cities. However, only three cities requested preliminary studies of the approach, and in each of these cities, the studies were abandoned before completion because of objections from the public, the business community, and key decision makers (*18*). Major objections were that it would interfere with the right to travel, that it would harm business or business image, and that it discriminates against the poor.

While the license approach to road pricing ran aground in the United States because of political problems, the success of another form of road pricing—toll roads—indicates that motorists are prepared to pay for convenient roads. The technical capability now exists to collect road tolls without stopping traffic. Users of the 14.5-mi-long Dallas North Tollway will be given the option of attaching to their vehicles electronic identification devices that will enable toll bills to be paid by monthly check, like electric or telephone bills. This technology could be used to establish a flexible toll system on urban area highways (*19*). Motorists who want to use a main artery—or designated lanes on those arteries—during peak-use periods first would be required to install in their automobiles a transponder, a relatively inexpensive device that emits a unique electronic signal identifiable by a central computer. This would permit the electronic tallying of each vehicle's use and allow a monthly bill to be generated. The computer could establish toll rates depending on the level of use, and displays near highway entrances or low-wattage radio signals could be used to advise motorists of the toll rates.

The review of the literature established a convincing need for further investigation of innovative transit service concepts, ridesharing incentives, and transportation pricing policies with particular reference to the Toledo area. To formulate appropriate strategies for computer testing, it was important to first project the magnitude of the traffic-congestion problems on specific facilities through the year 2010. These projections are discussed in the next section.

PEAK-PERIOD CONGESTION FORECASTS

The population of the Toledo transportation study area in 1980 was about 567,000. TMACOG's forecasts through 2010 indicate a 12 percent increase in population to 635,000, whereas employment is forecasted to grow by 23 percent from 235,000 to 290,000. Because of this growth and the continuing shift of population and employment to suburban locations along with increasing dependence on private vehicles for intraurban transportation, TMACOG has forecasted an increase in total daily vehicle miles of travel (VMT) of over 40 percent systemwide.

Forecasts of traffic congestion on the existing highway system based on an all-or-nothing traffic assignment are presented in Figure 1. Levels of service (LOS) D, E, and F in the peak periods are indicated. The forecasts show that both the freeway system and the arterial street system will be severely congested by 2010 if no improvements are made to the existing highway system or if travel demand is not managed. Under an optimistic scenario, TMACOG has estimated that a total of about $200 million in highway funding (in 1985 dollars) will become available over the next 20 years to pay for highway capacity improvements. This funding is estimated to be adequate for construction of about 100 new highway lane miles if existing rights-of-way can be used. It is clear that, even if right-of-way is available, the projected highway funding will not be adequate to relieve the forecasted levels of traffic congestion on the numerous miles of congested streets and highways indicated in Figure 1.

FORMULATIONS OF ALTERNATIVE STRATEGIES

Three alternative demand-management strategies were formulated to address the peak-period congestion problems. Each alternative strategy represents a "boundary" condition. A boundary condition may be defined as the upper limit in the severity of a range of policy levels that decision makers may be expected to consider. Each of the three strategies was a combination of extreme policies designed to encourage use of a more efficient travel mode or modes during peak travel periods. In addition, a "traditional" strategy was defined involving no travel demand-management policies, for use in comparative evaluation.

The traditional strategy reflected current policies. These policies involve primarily the expansion of the capacity of highway facilities. Most of the segments of the freeway/expressway system forecasted to be congested by the year 2010 would be widened under this strategy, using all of the $200 million in highway funding that is anticipated to become available (see Figure 2). Current peak-period transit service levels would be maintained. Only slight increases in auto operating costs and downtown parking costs are projected, based on market forces; no pricing policies are included.

The first demand-management strategy was a "transit-preferential" strategy, which included an extremely high level of peak-period transit service and pricing policies to encourage transit use and discourage auto use. Express bus service would be provided on reserved rights-of-way between transit centers at which high-density development would be encouraged (see Figure 3). All new freeway lanes would be reserved for transit. Feeder bus service would be provided to the centers, and park-and-ride facilities would be provided at several outlying centers. Peak-period transit fares would be reduced to half their current levels, and auto pricing policies (using tolls and parking charges) would double the cost of using the auto for the peak-period work commute.

The second demand-management strategy was a "ridesharing-preferential" strategy. Ridesharing would be encouraged through systemwide implementation of HOV lanes. All new lanes added to the freeway system would be reserved for HOVs (see Figure 4). Pricing policies would be the same as those under the transit-preferential strategy.

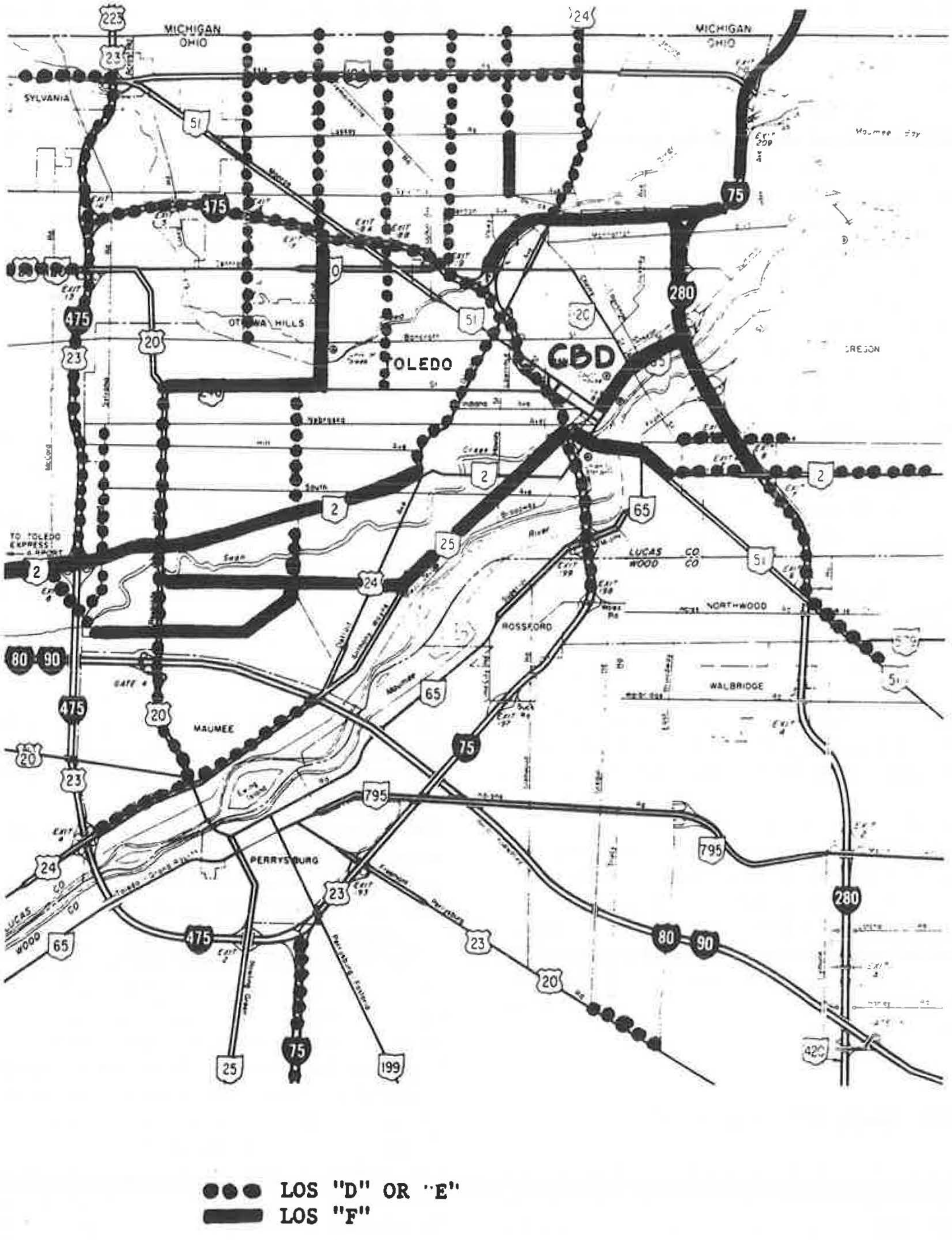

FIGURE 1 Projected year 2010 congestion.

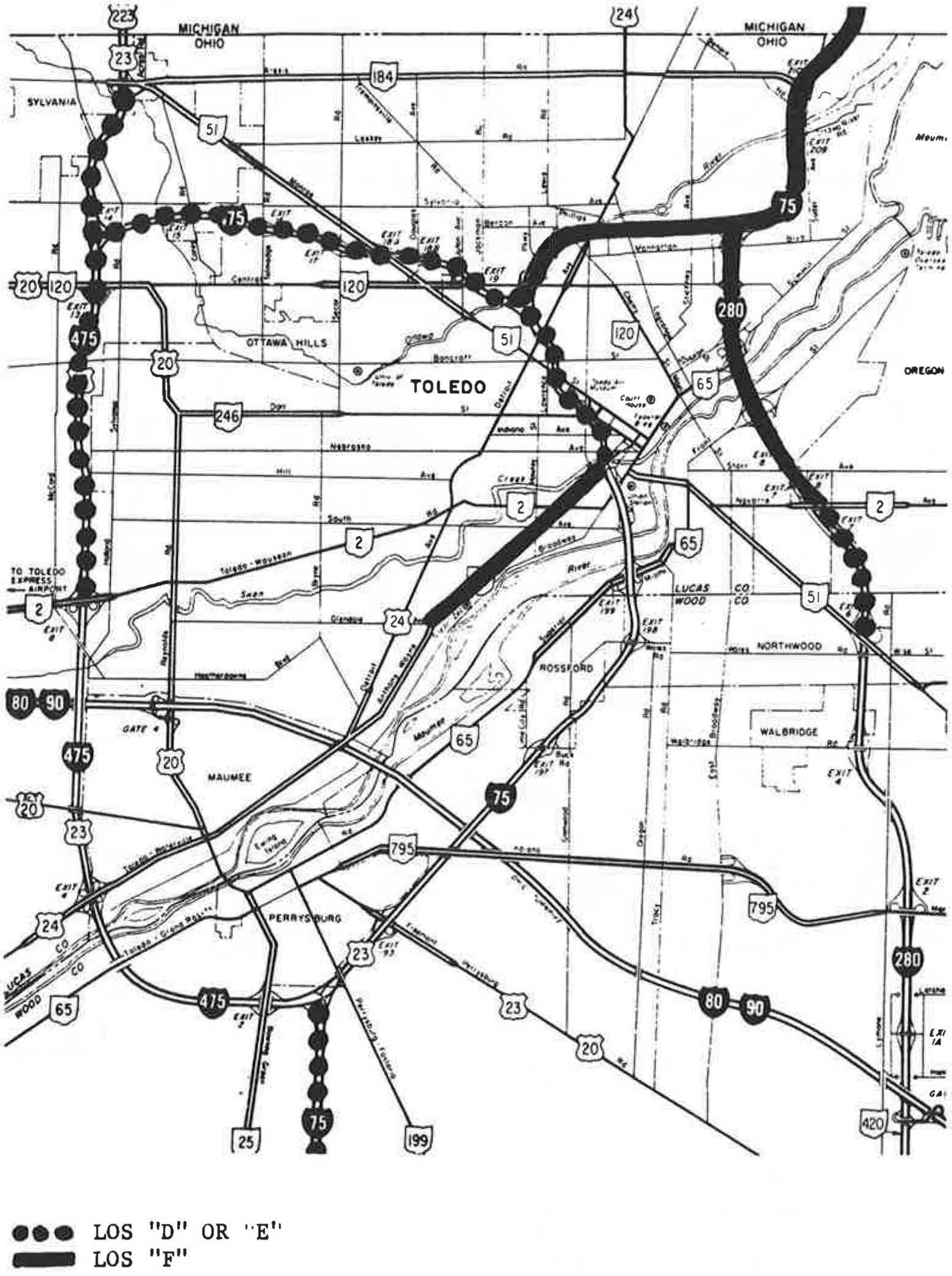

FIGURE 2 Projected year 2010 congestion on freeways and expressways.

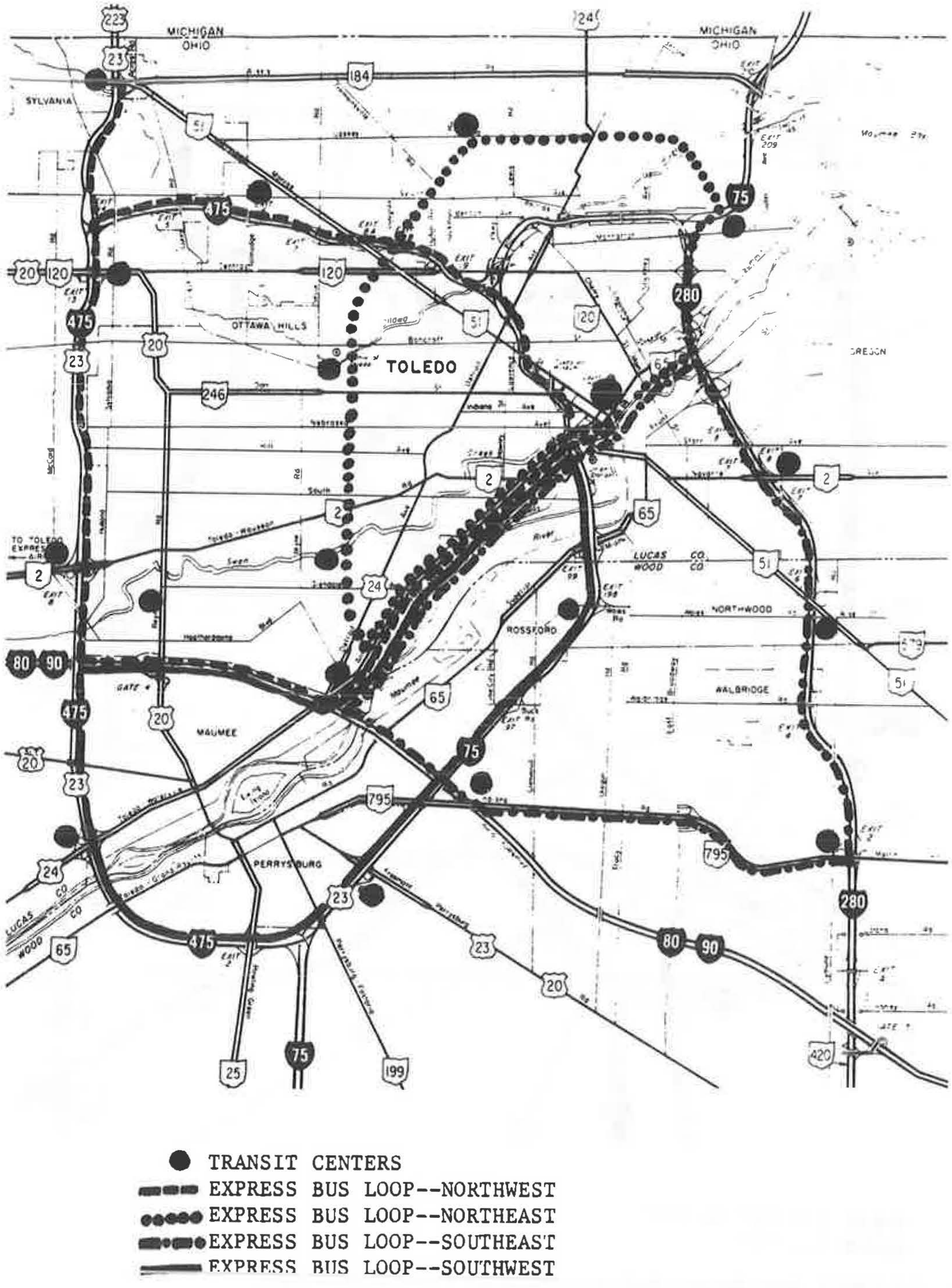

FIGURE 3 Multicentered transit system.

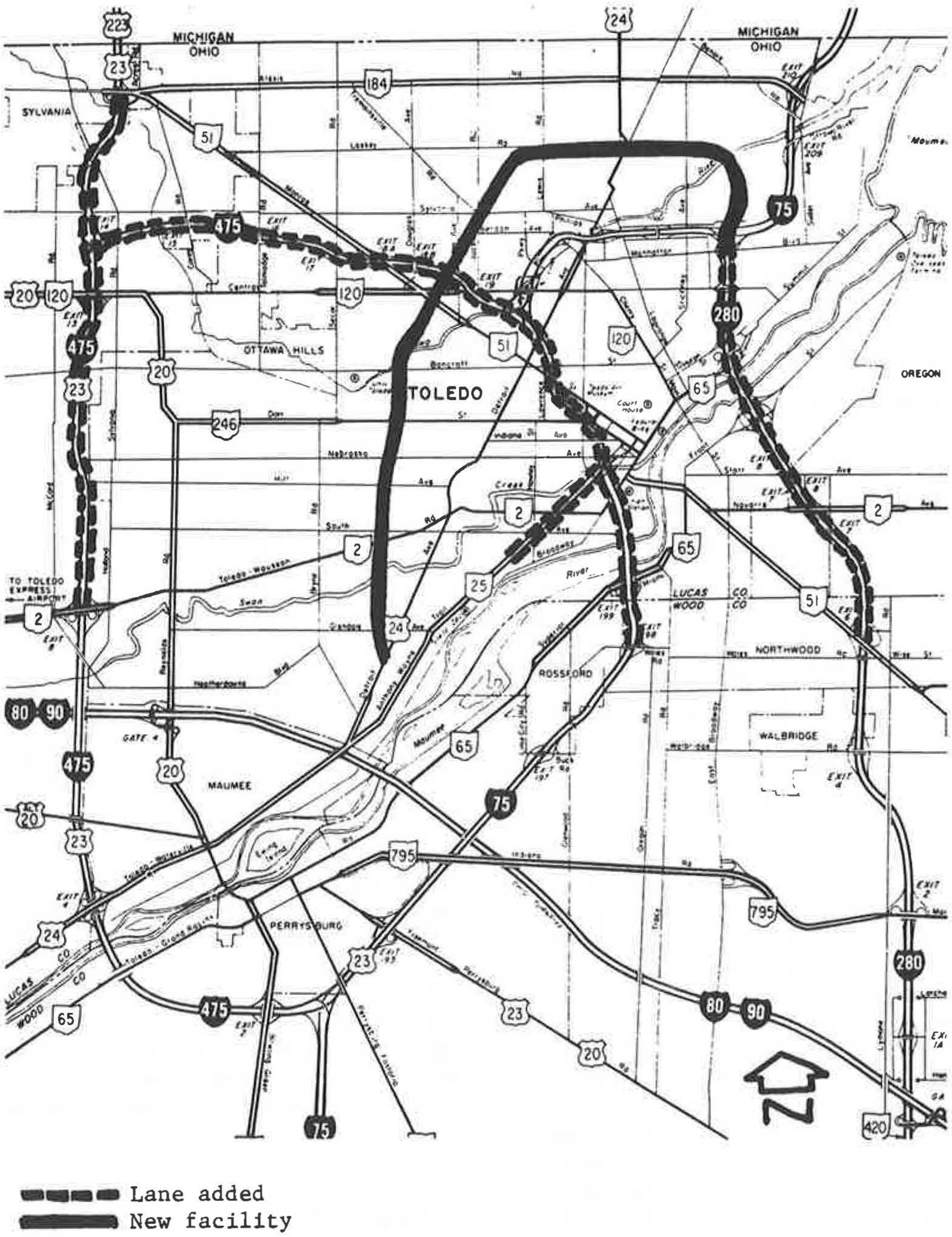

FIGURE 4 HOV lane system.

The third demand-management strategy was a combination of the first two. This "transit/ridesharing-preferential" strategy included the multicentered transit system of the transit-preferential strategy, with express bus service operating on the HOV lane system of the ridesharing-preferential strategy. Pricing policies were the same as those under the first two strategies.

TRAFFIC IMPACT ANALYSIS

The four transportation strategies described in the previous section were computer simulated using TMACOG's computerized travel models (*20*, *21*) and projected 2010 socioeconomic forecasts by traffic zone (*22*). Because the demand-management strategies were designed primarily to modify commuter travel demand, the analysis focused on the work trip. Separate runs of the mode-choice model were made for each strategy for work trips, but not for nonwork trip purposes; it was assumed that the demand-management strategies would have only minor effects on nonwork vehicular travel. Appropriate percentages of daily travel (*23*) were used to get peak-period shares of daily vehicle trips for the various trip purposes. The peak periods were defined as the 3 hours in the morning and the 3 hours in the afternoon with the highest traffic volumes, approximately 6:30 a.m. to 9:30 a.m. and 3:00 p.m. to 6:00 p.m. Results are summarized in Table 1.

TABLE 1 YEAR 2010 PEAK-PERIOD TRAVEL DEMAND

		Alternative Strategies		
	Traditional	Transit-Pref.	Rideshare-Pref.	Transit/R'share
Peak Period Work Travel:				
Person trips:				
Auto driver	257,524	169,314	193,669	165,117
Auto Passenger	61,208	68,189	99,762	77,690
Transit	12,090	93,319	37,392	88,015
Total person trips	330,822	330,822	330,823	330,822
Vehicle trips	257,524	169,314	193,669	165,117
Peak Period Total Vehicular Travel:				
Home-based work	257,524	169,314	193,669	165,117
Home-based non-work (31% of daily)	236,780	571,484	571,484	571,484
Non-home based (35% of daily)	184,149			
Truck & External (33% of daily)	150,555			
Total vehicle trips	829,008	740,798	765,153	736,601
% Change from traditional strategy		-10.6%	-7.7%	-11.1%

As shown in the table the combined transit/ridesharing-preferential strategy was the most effective of the three demand-management strategies with respect to reducing peak-period vehicular travel. Work vehicle trips were reduced by 36 percent, and total vehicle trips for all trip purposes were reduced by over 11 percent.

To estimate the impacts of these vehicular travel reductions on highway facility performance, peak-period vehicle trips were assigned to the highway network using an all-or-nothing traffic assignment. The assignment results were used to assess the impact of each strategy on traffic volumes that had previously been projected in 2010 if no improvements or demand-management policies were implemented (see Figure 1). The analysis focused on impacts in the vicinity of major activity centers. The results are presented in Figures 5 through 7. As shown in the figures, the demand-management strategies resulted in significant reductions in highway traffic volumes. Since the traditional strategy did not involve any policies to modify travel demand, no change in previously forecasted traffic volumes would result from the strategy; therefore a special traffic assignment was not needed.

EVALUATION OF ALTERNATIVES

The seven objectives adopted by TMACOG for its Year 2010 Plan (*24*) were economic efficiency, reduced traffic congestion, transit viability, economic development, safety, maximization of beneficial social impacts, and maximization of beneficial environmental impacts. The computer model estimates described in the previous section were used to develop quantitative information to evaluate the alternative strategies with respect to the first two objectives, traffic congestion relief and economic efficiency. The strategies were evaluated with respect to the remaining five objectives by comparing them based on indicators of the relative order of magnitude of their impacts with respect to the five objectives. In the next three subsections the evaluation results are presented with respect to (a) congestion relief, (b) economic efficiency, and (c) other impacts.

Congestion Analysis

As indicated in Table 1, a significant reduction in overall peak-period vehicular travel demand can be achieved by the alternative demand-management strategies. The combined transit/ridesharing-preferential strategy has the greatest impact on travel demand, reducing systemwide vehicular travel during peak periods by over 11 percent. The transit-preferential strategy has only slightly less impact, reducing travel by 10.6 percent, and the ridesharing-preferential strategy is the least effective, reducing overall travel by about 7.7 percent.

Vehicular travel demand must be viewed in relation to highway facility supply in order to assess traffic congestion levels. Because the alternative strategies involved varying levels of both travel demand and highway capacity available for unrestricted auto use, the ratios of volume to capacity were estimated for each strategy to evaluate congestion levels. The evaluation focused on five major activity centers that were

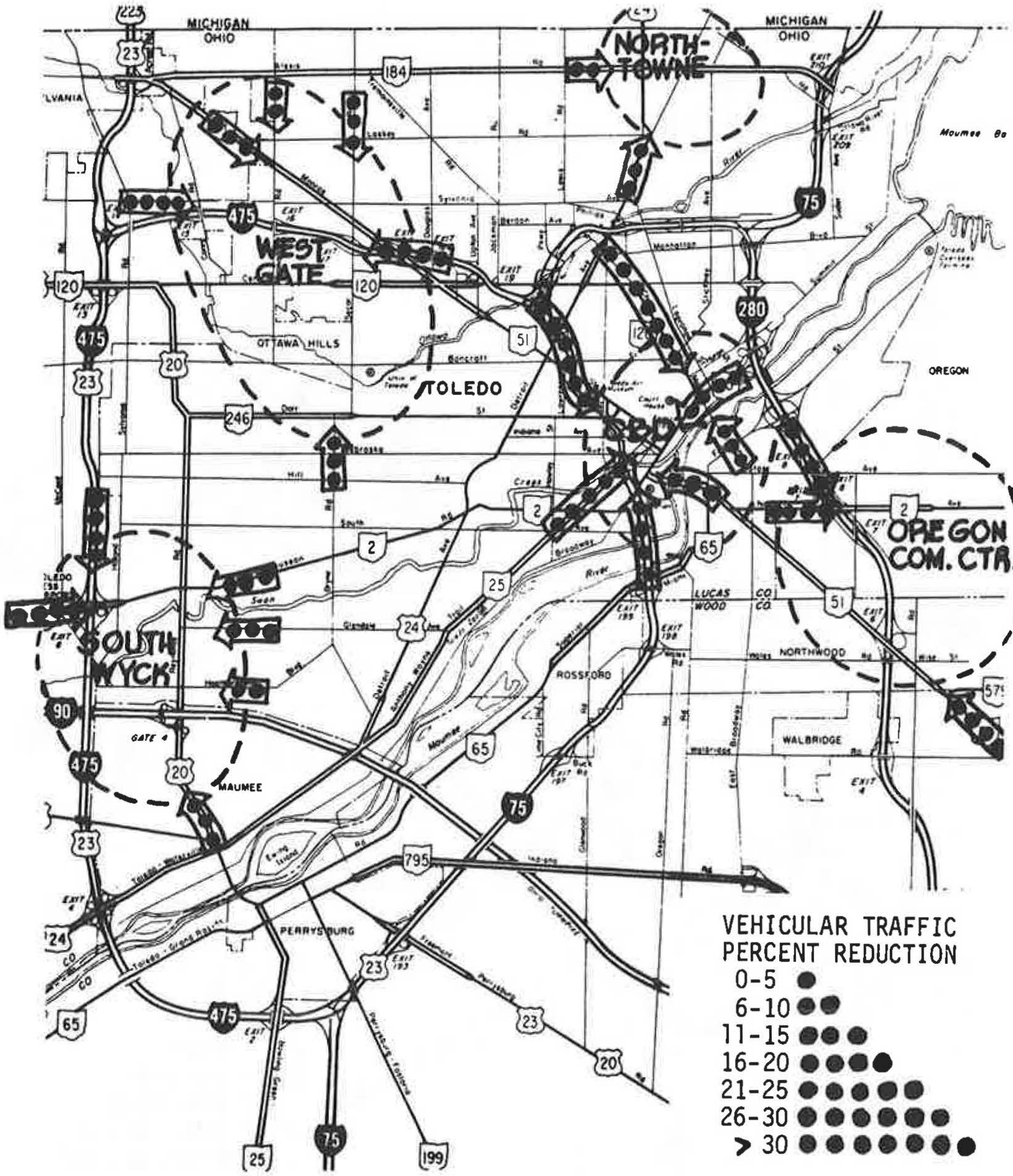

FIGURE 5 Vehicular traffic impacts in the vicinity of major activity centers—transit-preferential strategy.

of concern to policy makers. Ratios of volume to capacity (*V/C*) were developed for cordonlines around each of the five centers. The results are presented in Table 2. As indicated in the table, cordonline peak-hour *V/C* ratios were developed for the peak direction of travel. Traffic volumes in the peak hour in the peak direction were estimated based on the appropriate hourly distribution of travel on arterials (*23*). Capacity estimates were based on maximum volume that can be served at LOS C. The results of the analysis indicated that *V/C* ratios at LOS C would be lowest under the combined transit/ridesharing-preferential alternative, ranging from 0.92 to 1.08. It should be noted that, although traffic volumes are lowest under the transit-preferential alternative, the highway capacity added under this alternative is not available for auto use, since new lanes are reserved for buses. Consequently, *V/C* ratios are generally higher than for the other two demand-management alternatives, which allow use of added lanes by HOVs. It should also be noted that the *V/C* ratios represent average conditions along each cordonline. Actual *V/C* on specific facilities, or on specific lanes in the case of facilities with reserved lanes for HOVs, could be higher or lower than the average cordonline *V/C*.

Based on the *V/C* estimates in Table 2, it may be concluded that the combined transit/ridesharing strategy shows the greatest promise for relieving the forecasted congestion in the year 2010.

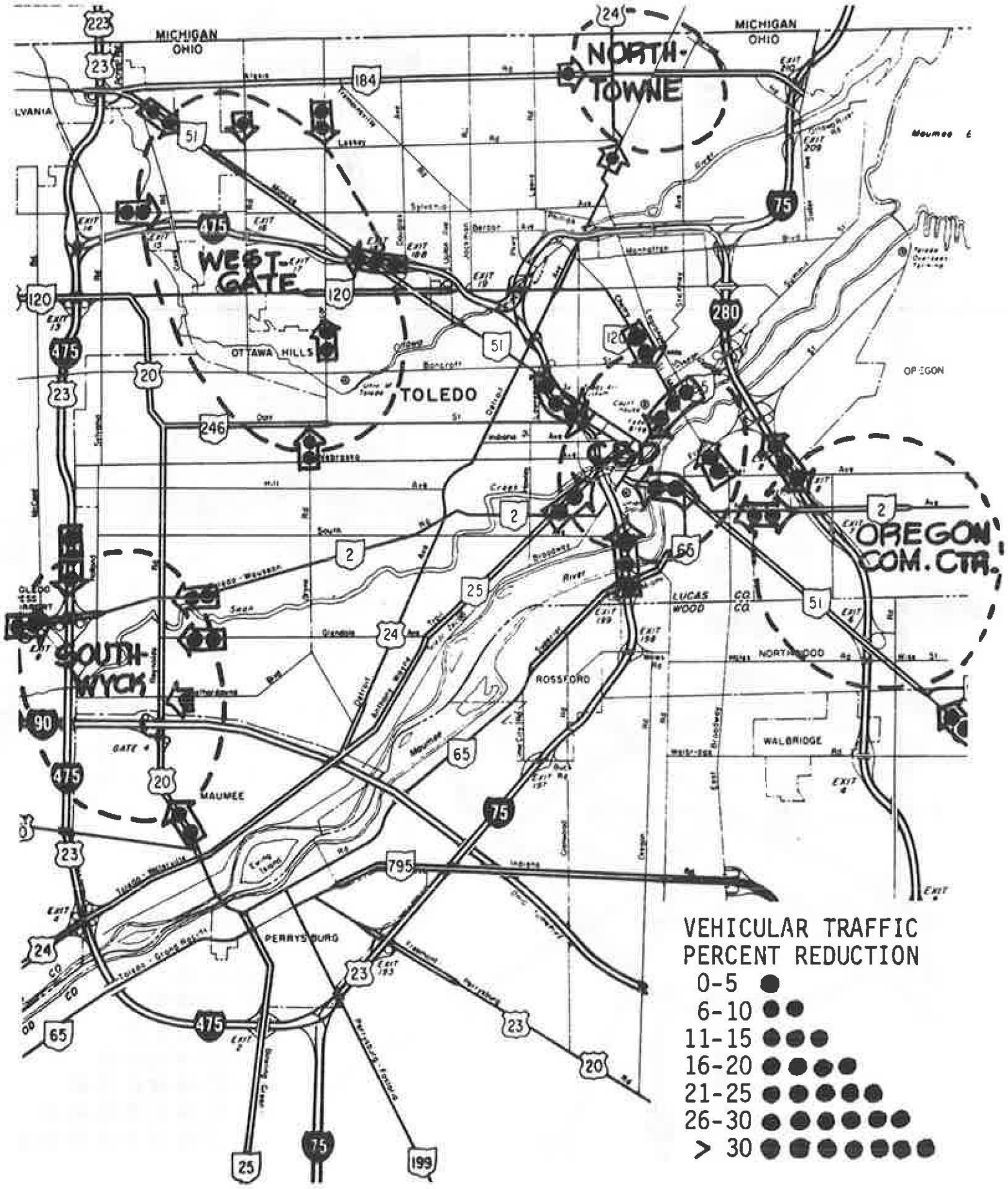

FIGURE 6 Vehicular traffic impacts in the vicinity of major activity centers—ridesharing-preferential strategy.

Economic Efficiency Analysis

The approach in economic efficiency evaluation is to compute total dollar costs of all economic resources used in the production of goods or services. In this analysis, the "service" to be produced through the transportation system is the satisfaction of work travel needs during the peak travel periods of the weekday in 2010 and beyond. Only resources that have dollar market values are considered "economic" resources. Thus, commuter travel time is generally not an economic resource (because most employees are not paid for the time they spend in getting to work) and has not been considered in the analysis.

Also, only "escapable" costs are considered in the analysis. For example, costs for auto ownership are not considered to be "escapable" because it is assumed that most solo-driver commuters who are induced to shift their travel mode to riding transit or carpooling will still need their cars for nonwork trips.

The economic resource costs were computed in 1985 dollars for each transportation strategy as follows:

- *Highway user costs.* Costs were based on vehicular operating and accident costs.
- *Highway facility costs.* All lane widening and new facility costs are considered "escapable" costs because it is assumed that all highway capacity improvements are needed mainly to serve peak-period travel volumes, and off-peak volumes can

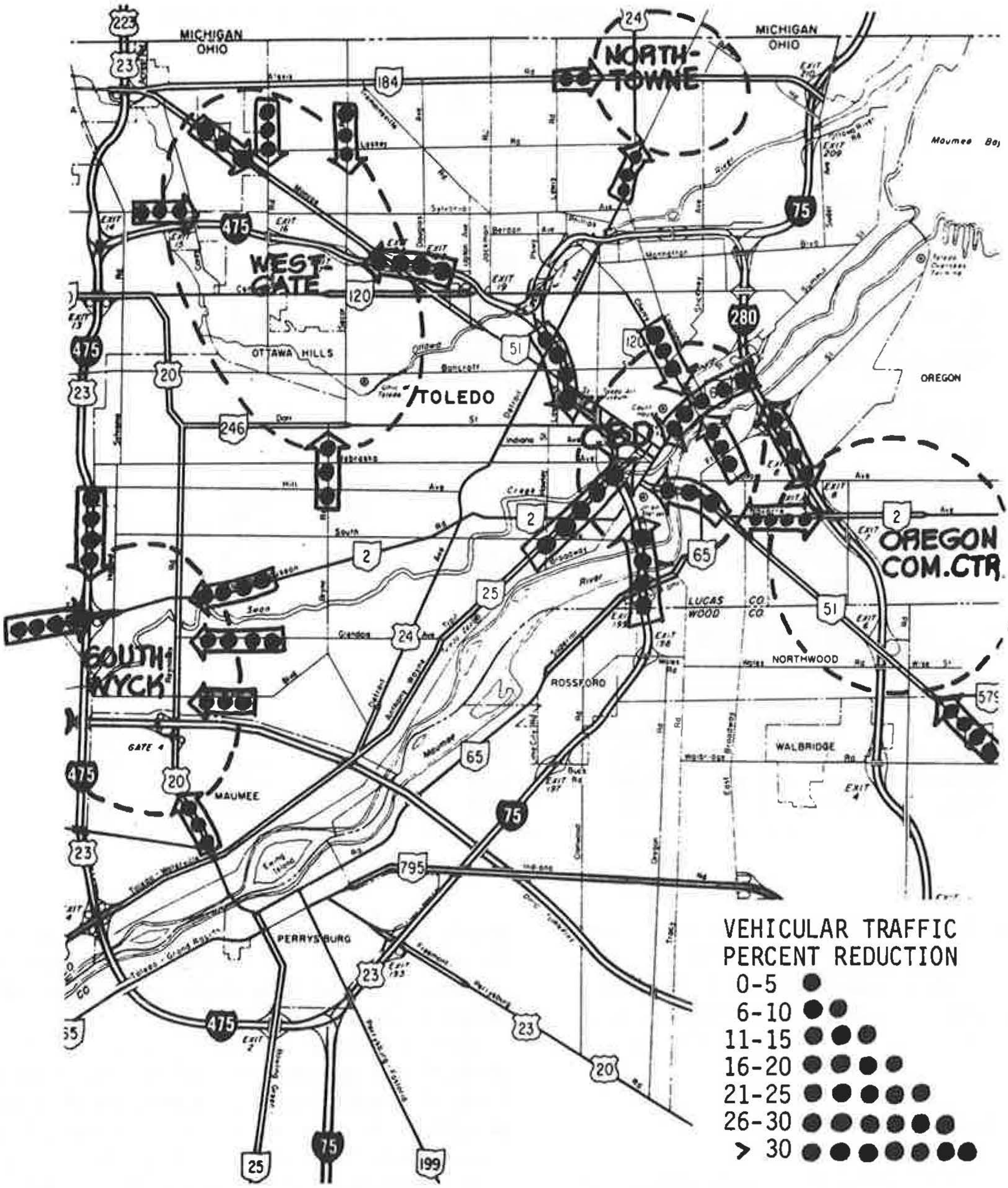

FIGURE 7 Vehicular traffic impacts in the vicinity of major activity centers—combined transit/ridesharing-preferential strategy.

be handled by existing facilities. The highway maintenance costs related to commuter work travel are estimated based on average annual maintenance costs.

- *Parking costs*. Only those parking spaces needed to serve commuters (not those for visitors) are considered "escapable." Both capital costs and maintenance costs are included.
- *Transit costs*. Capital costs of all buses needed for the system that exceed the number of buses needed for off-peak transit service are considered "escapable" costs. Operation and maintenance costs were estimated for peak-period service. Park-and-ride facility capital and maintenance costs are included. Busway/HOV-lane costs and metered freeway ramp bypass costs are reported as highway facility costs under the second bulleted item.
- *Employer/agency costs*. These include costs incurred by private employers and by government agencies for rideshare matching services and for administering a commuter parking management program.

Economic resource costs were computed for each of the five components of the transportation system (see Table 3). As shown in the table, highway user costs and employee parking costs are reduced considerably as a result of the travel demand strategies, whereas highway facility costs are slightly higher owing to specialized treatments for HOVs. Total annual resource cost is lowest for the transit/ridesharing-preferential strategy, amounting to $1.71 per work-person trip. This cost is over 16 percent lower than the cost per work-person trip

TABLE 2 YEAR 2010 HIGHWAY PERFORMANCE IN THE VICINITY OF MAJOR ACTIVITY CENTERS

	Major Activity Centers				
	Downtown	Southwyck	Westgate	Northtowne	Oregon
Cordonline traffic volumes (peak hour, peak direction):					
Do-nothing alternative	20,199	11,988	13,040	2,655	6,569
Traditional	20,199	11,988	13,040	2,655	6,569
Transit preferential	16,577	10,718	11,069	2,382	5,393
Ridesharing preferential	17,991	10,948	12,059	2,555	5,745
Combined alternative	16,584	10,320	11,064	2,370	5,390
Cordonline directional hourly capacity (LOS C):					
Do-nothing alternative	15,020	8,805	10,015	2,265	5,137
Traditional	17,950	9,556	11,216	2,265	5,888
Transit preferential	15,020	8,805	10,015	2,265	5,137
Ridesharing preferential	17,950	9,556	11,216	2,265	5,888
Combined alternative	17,950	9,556	11,216	2,265	5,888
Cordonline peak hour, peak direction volume-to-capacity ratios (at LOS C):					
Do-nothing alternative	1.34	1.36	1.30	1.17	1.28
Traditional	1.12	1.25	1.16	1.17	1.11
Transit preferential	1.10	1.22	1.11	1.05	1.05
Ridesharing preferential	1.00	1.15	1.08	1.12	0.98
Combined alternative	0.92	1.08	0.99	1.05	0.92

of $2.05 under the traditional strategy. It should be noted that these costs exclude the value of travel time. If travel delay costs are included, the cost difference would be even greater because vehicular travel delays are much greater under the traditional strategy as a result of higher *V/C* ratios.

Analysis of Other Impacts

Relative performance of the alternative strategies with respect to the five remaining plan objectives was assessed by comparing them with one another based on performance indicators (see Table 4). The performance indicators were developed from the travel-demand, highway-performance, and economic-resource cost estimates presented in Tables 1 through 3. Transit system costs per peak-period rider and peak-period ridership levels were selected as indicators of transit viability. Assuming that economic development potential would be enhanced by lower levels of congestion, the weighted average *V/C* ratio for the five major activity centers was selected as the indicator of performance with respect to economic development. Indicators selected to evaluate safety were (a) VMT per work-person trip served, which measures relative exposure to probability of an accident, and (b) congestion levels, which tend to reduce the severity of accidents (because of lower speeds) but increase their probability. Indicators selected to evaluate social benefits were the extent of transit coverage and its level of service, which would benefit the transportation disadvantaged (i.e., the elderly, handicapped, poor, and others unable to drive). Finally, daily work VMT in peak periods was used as an indicator of negative environmental impacts such as air pollution, noise, and consumption of nonrenewable energy resources.

The four alternative strategies were evaluated comparatively, that is, the strategies with the lowest and the highest levels of performance were identified with respect to each objective, and the remaining two were identified as being "intermediate" in performance level. As indicated in Table 4, the combined transit/ridersharing-preferential strategy performed at the highest level while the traditional strategy performed at the lowest level with respect to all five objectives.

Summary

Figure 8 graphically presents the performance of the four strategies. Performance against the seven objectives is represented by four indicators of major importance to allow easier assimilation of the information for subjective evaluation by decision makers. The selected measures were as follows:

- *Percentage by which cordonline traffic volumes at major activity centers exceed LOS C capacity*, indicating congestion relief and economic development potential of each strategy.
- *VMT per work-person trip*, indicating safety and environmental impacts of each strategy.
- *Transit system cost per rider*, indicating transit viability and social benefits of each strategy.

TABLE 3 ANNUAL ECONOMIC RESOURCE COSTS

	Traditional	Transit-Pref.	Rideshare-Pref.	Transit/R'share
Highway user costs:				
Vehicle operation	$58.9	38.7	44.3	37.8
Accident cost	6.5	4.3	4.9	4.2
Sub-total	65.4	43.0	49.2	42.0
Highway facility costs:				
Construction	23.3	28.4	28.4	28.4
Operation & maintenance	5.9	3.9	4.4	3.8
Sub-total	29.2	32.3	32.8	32.2
Employee parking costs:				
Construction	30.0	19.7	22.0	19.2
Operation & maintenance	42.2	27.6	31.2	21.5
Sub-total	72.0	47.3	53.2	40.7
Transit system costs:				
Buses and garage space	3.8	15.5	8.4	14.3
Service operation & maint.	5.8	14.5	8.9	13.7
Park-and-ride construction	0.0	0.7	0.0	0.7
Park-and-ride maintenance	0.0	1.4	0.0	1.4
Sub-total	9.6	32.1	17.3	30.1
Employer/agency costs:				
Ridesharing matching	0.1	0.1	3.9	1.6
Parking management	0.0	0.1	0.1	0.1
Sub-total	0.1	0.2	4.0	1.7
TOTAL RESOURCE COST	176.3	154.9	156.5	146.7
COST PER WORK TRIP (dollars)	2.05	1.81	1.82	1.71

- *Economic resource cost per work trip*, indicating economic efficiency of each strategy.

The lower the magnitude of each indicator, the better the performance of the alternative. Figure 8 shows clearly that the combined transit/ridesharing-preferential strategy performs the best (i.e., has the lowest values with respect to every indicator), whereas the traditional strategy has the worst performance (i.e., has the highest values with respect to every indicator). The transit-preferential strategy generally performs better than the ridesharing-preferential strategy with respect to every indicator except percent over capacity.

CONCLUSIONS AND RECOMMENDATIONS

The evaluation of the four alternative strategies indicates that a combined strategy to encourage both ridesharing and transit use during peak periods can reduce forecasted levels of congestion significantly and at the same time provide effective performance with respect to TMACOG's other plan objectives. Therefore, the following recommendations were developed and adopted by TMACOG's Long Range Plan Task Force:

- A more detailed study should be conducted to examine the need, design, priority, and staging of a multicentered rapid-transit bus system with timed transfers and feeder bus service; land use policies should be examined to encourage high-density mixed-use development at transit centers to maximize transit system viability.
- Commuter parking policies and road pricing policies should be developed to eliminate the current incentives for solo driving.
- A study of the feasibility of an HOV lane system should be undertaken in conjunction with TMACOG's currently proposed Interstate Highway Needs Study (*8*).

Further research is recommended with respect to the following issues:

- Impact of demand-management strategies (including pricing) on mode choice for nonwork trip purposes and peak spreading.

TABLE 4 RELATIVE PERFORMANCE WITH RESPECT TO OTHER OBJECTIVES

			Alternative Strategies		
		Traditional	Transit Pref.	R'share Pref.	Transit/ R'Share
1.	Transit viability:				
	Work peak period ridership daily	12,090	93,319	37,392	88,015
	System cost per rider	$ 3.05	$ 1.32	$ 1.78	$ 1.32
	Relative assessment	Lowest	Highest	Intermed.	Highest
2.	Economic development potential:				
	Average V/C for activity centers	1.16	1.12	1.05	0.98
	Relative Assessment	Lowest	Intermed.	Intermed.	Highest
3.	Safety:				
	VMT per work person trip*	6.85	4.50	5.15	4.39
	Average V/C for activity centers*	1.16	1.12	1.05	0.98
	Relative assessment	Lowest	Intermed.	Intermed.	Highest
4.	Social benefits:				
	Transit coverage and LOS	Minimum	Maximum	Minimum	Maximum
	Relative assessment	Lowest	Intermed.	Intermed.	Highest
5.	Environmental benefits:				
	Daily work VMT in peak periods**	2.27 mil.	1.49 mil.	1.70 mil.	1.45 mil.
	Relative assessment	Lowest	Intermed.	Intermed.	Highest

* Accident rates are directly proportional to VMT and congestion levels.

** Carbon monoxide, hydrocarbon and nitrogen oxide emissions are directly proportional to VMT.

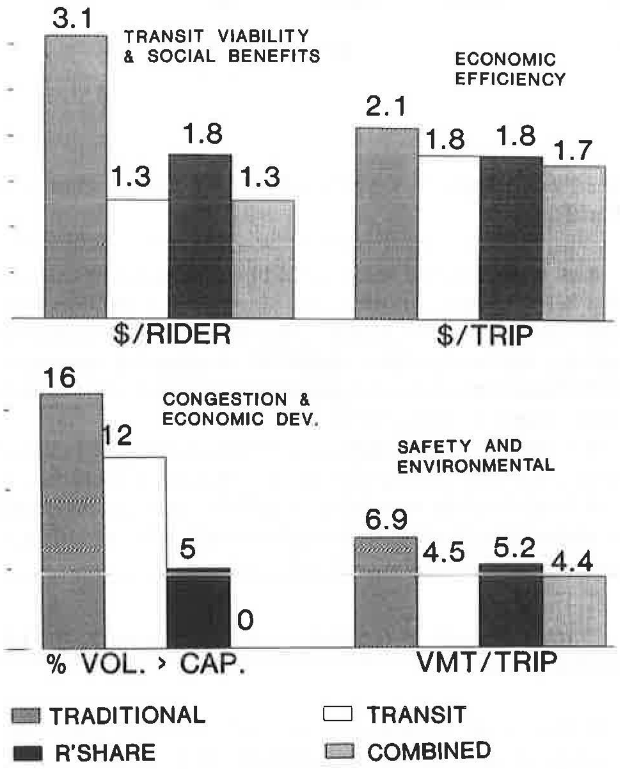

FIGURE 8 Indicators of performance.

- Impacts of demand-management strategies on noneconomic resource costs (e.g., travel time and delay costs).
- Development of technical procedures to guide transportation planners in the analysis and evaluation of the impacts of systemwide strategies to manage travel demand.
- Development of solutions to technical and institutional problems relating to road pricing, including procedures to quantify perceived adverse impacts of road pricing and development of methods to ameliorate adverse impacts.

It should be noted that the risks in implementing the combined transit/ridesharing system in conjunction with pricing policies are quite high, and the hurdles to be overcome with respect to road pricing in particular are immense. If the Toledo area, or any other metropolitan area, is to achieve success in implementing the concept, demonstration funding will be required from state or federal levels of government. A state or federal demonstration program is suggested to provide technical and funding assistance to metropolitan areas that show interest in implementing innovative combinations of transit, ridesharing, and pricing policies to meet the challenge for urban transportation in the 21st century.

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REFERENCES

1. *Highway Capital Spending Capability Through the Year 2010.* Toledo Metropolitan Area Council of Governments, Toledo, Ohio, June 1987.
2. P. deCorla-Souza, H. Salverda, and D. Beckwith. Public Involvement Process for Identifying Problems and Alternate Solutions for the Year 2010 Transportation Plan. In *Transportation Research Record 1167*, TRB, National Research Council, Washington, D.C., 1988, pp. 11–20.
3. P. P. Belobaba. Rapid Transit Development in Medium-Sized Urban Areas: A Comparison of Planning and Decision Making in Two Canadian Cities. In *Transportation Research Record 877*, TRB, National Research Council, Washington, D.C., 1982, pp. 12–19.
4. J. Bonsall. A Bus for All Seasons. Presented at the seminar on "The Canadian Experience: Making Transit Work in the Golden Gate Corridor," cosponsored by the Golden Gate Bridge Highway and Transportation District and the Canadian Consulate General, San Rafael, Calif., Oct. 3, 1985.
5. R. J. Fisher. Shirley Highway Express Bus on Freeway Demonstration Project. In *Highway Research Record 415*, 1972, pp. 25–37.
6. D. L. Christiansen. Freeway Transitways as a Means of Serving Regional Travel Demand—The Texas Experience. Presented at the National Conference on Transportation Planning Applications, Orlando, Fla., April 1987.
7. D. G. Capelle, C. A. Fuhs, and B. L. Pearson. A Transitway Development Program for Orange County, California. Presented at the 57th Annual Meeting of the Institute of Transportation Engineers, New York, N.Y., Aug. 1987.
8. *Toledo Metropolitan Interstate Highway Needs Study.* Toledo Metropolitan Area Council of Governments, Toledo, Ohio, Aug. 1987.
9. R. Nakadegawa. The Neglected Alternative. *Passenger Transport*, Aug. 24, 1987, pp. 1, 9.
10. J. Schneider et al. *Planning and Designing a Transit Center Based Transit System: Guidelines and Examples from Case Studies in Twenty-Two Cities.* UMTA, U.S. Department of Transportation, Sept. 1980.
11. J. J. Bakker. Advantages and Experiences with Timed Transfers. Presented at the 60th Annual Meeting of the Transportation Research Board, Washington, D.C., 1981.
12. D. E. Priest and J. L. Walsh-Russo. Land Use Trends and Transit Operations. In *Special Report 199: Future Direction of Urban Public Transportation*, TRB, National Research Council, Washington, D.C., 1983, pp. 37–46.
13. R. Cervero. Urban Transit in Canada: Integration and Innovation at Its Best. *Transportation Quarterly*, July 1986, pp. 293–316.
14. D. A. Newman, B. Marlies, and J. McNally. *Timed Transfer: An Evaluation of Its Structure, Performance and Cost.* UMTA, U.S. Department of Transportation, 1983.
15. D. C. Shoup. Cashing Out Free Parking. *Traffic Quarterly*, Vol. XXXVI, No. 3, July 1982, pp. 351–364.
16. L. C. Fitch and Associates. *Urban Transportation and Public Policy*, Chandler, 1964.
17. E. P. Holland and P. L. Watson. Traffic Restraint in Singapore. *Traffic Engineering and Control*, Vol. 19, 1978, pp. 14–22.
18. T. Higgins. The Politics of Impact: The Case of Road Pricing. In *Transportation Research Record 747*, TRB, National Research Council, 1980, pp. 29–34.
19. F. N. Wilner. One Solution for Near-Gridlock: Charge for the Roads in Rush Hour. *Fairfax Journal*, Oct. 19, 1988.
20. *Refinement of Travel Models, Volume 1.* Toledo Metropolitan Area Council of Government, Toledo, Ohio, April 1986.
21. *An Evaluation of TMACOG's Refined Travel Models, Part II.* Toledo Metropolitan Area Council of Governments, Toledo, Ohio, July 1986.
22. *Projection of Travel Model Input Data for the Year 2010, Volume 1.* Toledo Metropolitan Area Council of Governments, Toledo, Ohio, July 1986.
23. A. B. Sosslau, A. B. Hassam. M. M. Carter, and G. Wickstrom. *NCHRP Report 187: Quick-Response Urban Travel Estimation Techniques and Transferable Parameters, User's Guide.* TRB, National Research Council, Washington, D.C., 229 pp.
24. *2010 Transportation Plan Goals, Objectives and Planning Process.* Toledo Metropolitan Area Council of Governments, Toledo, Ohio, June 1986.

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Abridgment

Accommodating Deaf and Hard-of-Hearing Persons on Public Transportation Systems in Massachusetts

GARY R. BETTGER AND TIMOTHY J. PEARSON

The Massachusetts Executive Office of Transportation and Construction commissioned this study because no definitive information exists to form transit policy for the hearing impaired. The study notes the types of problems experienced by the hearing impaired, who frequently lack access to oral communication when using bus, subway, and airplane transportation. The results are missed connections, significant delays, and increased risk in emergencies. Transportation personnel who are not prepared to communicate with the hearing impaired and inaccurate destination information compound the problem. Transportation officials have concentrated on the needs of the mobility and vision impaired. This study suggests, however, that there is rough parity in size among the hearing-, vision-, and mobility-impaired populations. Planners should take account of the needs of the hearing impaired as well as these other populations. Several technologies and methods exist to lessen the problems faced by the hearing impaired. These vary in cost and applicability in transportation settings. In the short term, however, officials can implement low-cost improvements such as installation of amplified telephones and telecommunication devices for the deaf (TDDs), provision of accurate route schedules, and use of note slips on buses. In the long term, we suggest installation of electronic readerboards, visual emergency alarms, and touch screen video monitors and use of sensitivity training sessions.

The hearing impaired frequently lack access to oral communication when using subway, bus, and airplane transportation. The results are missed connections, significant delays, and increased risk in emergencies. Personnel who are not prepared to communicate with the hearing impaired and inaccurate route information compound the problem.

The Massachusetts Executive Office of Transportation and Construction commissioned this study because no definitive information exists to form transit policy that takes into account the needs of the hearing impaired. In a longer report we detail cost information and suggest specific design recommendations by travel mode for the Commonwealth of Massachusetts. However, this abridgment contains some overall lessons and suggestions for transportation planners nationwide.

To develop a policy framework, we assess the types of problems experienced by hearing-impaired people and some demographic characteristics of the population. We discuss potential technologies and methods available to lessen the problems faced by the hearing impaired on public transportation. Finally, we suggest some short- and long-term improvements that transportation officials can implement.

PUBLIC TRANSPORTATION PROBLEMS FOR THE HEARING IMPAIRED

People with hearing impairments confront a series of situations on public transportation that pose difficulty, although not all of the situations will lead to problems on every trip and some problems are also faced by the general population. Let us consider a few key access points for the hearing impaired in different modes of travel:

- Bus:
    - Accessing schedule and destination information through printed material or, if over the phone, through use of a telecommunication device for the deaf (TDD).
    - Communicating with the driver through sign language or written notes.
- Subway:
    - Using signs and system maps to obtain destination information.
    - Relying on transit personnel who may be unable to communicate effectively with the hearing impaired.
    - Obtaining information from public address announcements, such as a change in train status from local to express or directions in an emergency.
    - Obtaining information on the train about upcoming stops.
    - Relying on amplified phones or TDDs to make outgoing phone calls.
- Airplane:
    - Accessing emergency voice boxes in parking garages.
    - Obtaining information regarding flight announcements.
    - Relying on signs to know destination information.

HEARING-IMPAIRED POPULATION

There are many points along a typical public transportation trip where the hearing impaired face difficulty. In fact, many of the problems are present in all three modes of travel. How many people will benefit from improvements?

In 1985, the National Center for Health Statistics estimated

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that 9.1 percent of the population, or 21.2 million, had a hearing impairment (*1*, p. 1). The hearing-impaired population is defined as those persons reporting any type of hearing problem. Approximately 10 percent of the hearing impaired can be considered to be severely or profoundly deaf (*2*, Tables 62 and 78). Most of the hearing-impaired population can understand some auditory messages either unaided or with hearing aids. Consequently, many could benefit from audio, as well as video, accessibility improvements. However, we suggest that transportation planners not overemphasize the distinction between the deaf and hard-of-hearing. In noisy environments, the hard-of-hearing may become functionally deaf.

How does the number of potential hearing-impaired users compare with other special-needs populations? In Massachusetts, we found that there is rough parity in size among the different populations, even when using various definitions. These numbers suggest that there is a significant hearing-impaired population that could be assisted by modifications to transit systems. Planners should ensure that policy actions include this population.

TECHNOLOGY AND TRAINING

Many types of technologies are currently available for the hearing impaired: amplifiers and receivers, induction loops, visual displays, and TDDs. Transit authorities also use sensitivity training to alert staff to needs of the hearing impaired.

Amplifiers and Receivers

Amplifiers and receivers include FM and infrared systems that convert announcements into FM or infrared signals. The signals are then picked up by a receiver and stereo headset. The advantage of such systems is that they offer high-quality sound. Yet, the disadvantages are numerous in a public transportation setting. For example, use requires individual receivers, and few people possess their own units. Furthermore, public use is typically limited to a quiet, stationary setting such as a theater. Finally, such systems are relatively expensive.

Induction Loop

The induction loop functions by creating a magnetic or induction field that can be picked up by the telecoil in a hearing aid. Induction loops are typically used in private homes, classrooms, and meeting rooms. For the loop to function effectively, the entire circumference of the area should be encircled. Individuals set a switch on their hearing aid to the telecoil or T-position.

The advantages of the induction loop are that it connects easily to existing public-address (PA) systems and it assists those most profoundly deaf. However, we do not recommend induction loops for transportation settings. Metal in vehicles, electromagnetic fields, and the use of fluorescent lights in buildings make use of loops impractical. The interference of radio transmissions and the fact that only a small percentage of the hearing impaired wear hearing aids with T-switches are further disadvantages.

Video Monitors

Many companies market video monitor systems that use television screen monitors to televise commuter rail information, as well as news and advertising. Systems intermingle numerous pages of text and rotate different pages on a periodic cycle. The advantages of this technology are that it provides updated information systemwide to the hearing impaired and other riders and that it can be subsidized through advertising revenues. However, because highly visible information is particularly important, we have reservations about the usefulness of monitors to the hearing impaired in subway stations. Monitors are particularly useful when schedule information is detailed and fairly constant such as at airports. However, visibility is a key criterion. The letter size on monitors is small when compared to the standard 7-in. size possible on readerboards. In addition, people may not be attracted to screens with stationary graphics. Thus, on the basis of visibility, we recommend the use of readerboards, rather than video monitors, in subways.

Electronic Readerboards

Electronic readerboards use either digital or liquid electronic display (LED) technology. The latter scrolls messages across a screen like many of the signs seen in New York's Times Square. The oldest readerboards are self-contained and have as many as 16 computer chips, each programmed with specific one-sentence messages. Updating messages is time-consuming. Newer systems are more centrally controlled.

The advantage of readerboards is that a computer can instantly update information and send it systemwide or to selected readerboards. Both hearing-impaired and other passengers can benefit. On the other hand, readerboards with incandescent bulbs are energy intensive and have high maintenance costs. In addition, LED readerboards can be difficult to read from an angle.

Overall, however, electronic readerboards are the best means of providing access to infrequent verbal information such as PA train delay and paging announcements. LED readerboard systems are preferable to incandescent digital readouts because of their lower energy and maintenance costs. When detailed bus, train, or flight schedules must be continually available, video monitors are preferred.

We do not recommend placing readerboards inside subway cars. The technology is available, but emergency warning lights that are well labeled are a better safety solution. In addition, destination information on the train can be less expensively supplied using system maps inside cars in combination with signs on the platforms.

TDDs and Phone Amplifiers

TDDs, which resemble small typewriters with a screen or printer, allow the hearing impaired to make telephone calls. The TDD eliminates the need for an interpreter but it does require that another TDD be used at the other end. TDDs have decreased in cost and increased in use.

Phone amplifiers are used to increase the volume of public pay phones. They are typically placed in the phone receivers but recent attempts to vandal-proof the phones have resulted in the placement of the amplifiers in the body of the phone.

The advantage of these two technologies is that their cost is relatively low and falling. Furthermore, their use is expanding so people are becoming more familiar with them. On the other hand, precautions have to be taken to avoid vandalism directed at the units.

Schedule and transit information is generally available to the hearing impaired via TDDs. However, TDD numbers need to be widely publicized among the hearing-impaired population. Steps are being taken to install TDD units in subway stations and airport terminals. We support these measures. Because the cost of TDD units has fallen significantly, their use should be expanded. The cost of amplifying devices on public pay phones has also dramatically declined. It should be noted that there are federal regulations relating to placement of amplified phones, which must be complied with.

Sensitivity Training

Most transit authorities provide a general orientation to new employees that includes information on how to deal with the physically handicapped. Some transit authorities also discuss the needs of the hearing impaired and provide personnel with a short manual explaining how to sign important messages. A few authorities even provide annual refresher courses.

Not all information can be provided to passengers by signs, visual displays, and emergency signals; therefore, transit personnel need to be trained on how to communicate with the hearing impaired. Such training should be part of a new employee's orientation and be repeated periodically. Ideally, training should be conducted by people who are hearing impaired themselves. Ticket booth attendants and those at information desks should also have manuals or laminated cards describing the most essential sign phrases.

Accurate Signs and Schedules

Those with hearing impairments are even more dependent than the general public on printed information. Thus, signs and schedules should be available in adequate number. Because obtaining verbal clarification is complicated by hearing impairment, the accuracy of signs and schedules is essential.

CONCLUSION

Transit authorities are just now becoming aware of the needs of the hearing impaired in transportation settings. Clearly, with budget constraints, planners will have to choose from the alternatives given in this paper. These can be broken down into low-cost, short-term and more expensive long-term improvements.

Transit authorities should consider these low-cost and relatively simple improvements in the short term:

- Provision of TDD information numbers.
- Installation of amplified phones and TDDs.
- Provision of accurate and adequate transit schedules.
- Use of note slips for communication with bus drivers.

The following improvements should merit consideration for the long term:

- Installation of electronic readerboards.
- Installation of visual emergency alarms.
- Use of sensitivity training sessions.
- Installation of touch screen video monitors.

Realistically, not all of these recommendations can be implemented immediately. However, it is important to remember the following points:

- Over 9 percent of the population depend on visual information.
- Where the hearing listen, the hearing impaired must read.
- Emergency alarms for the hearing impaired must be visual.
- Personnel are the final alternative if technology fails.

Planners should ensure that policy reflects the needs of the hearing impaired. In fact, actions taken on their behalf often benefit all riders. Transit authorities have a foundation on which to build accessible systems for the hearing impaired.

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REFERENCES

1. D. Hotchkiss. *Demographic Aspects of Hearing Impairment.* Center for Assessment and Demographic Studies, Gallaudet University, Washington, D.C., 1987.
2. *Data from the National Health Survey.* Series 10, No. 160. National Center for Health Statistics, Hyattsville, Md., 1987.

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Quick Approach To Compare Highway and Bus Transit Alternatives Using the Arterial Analysis Package

FAZIL T. NAJAFI AND FADI EMIL NASSAR

A quick approach to evaluate two types of transportation investments is presented in this paper. The investments are (a) adding lanes to an existing highway, or (b) providing an express bus service (park-and-ride). The procedure focuses on congestion relief, and the only measure of effectiveness considered is delay. The Arterial Analysis Package (AAP) software, developed at the University of Florida, is used to compute delays for the alternatives considered. The quick-response method is not intended to replace the need for a comprehensive investment analysis. It provides a quick indicator of how public investments perform toward reducing traffic delays. The procedure is most effective when dealing with major urban streets operating at a poor level of service caused by limited intersection capacities. Typically, right-of-way costs for additional lanes on similar streets are expensive. Such corridors are the ones considered for some type of transit solution. The express bus is one solution that requires minimum capital cost and offers maximum flexibility.

A quick approach (QA) to evaluate and compare the cost-effectiveness of adding lanes to an existing highway or investing in a park-and-ride express bus system (EBS) is presented in this paper. The EBS system could serve as a transitional step or a final solution to relieve a congested corridor. The QA permits the analysis of traffic operation on managed [high occupancy vehicle (HOV)] or nonmanaged (no preferred treatment) lanes.

The QA is illustrated with a case study of a congested corridor, Dale Mabry Avenue, located within the city of Tampa, Florida. The following alternatives are considered:

- Adding one lane (nonmanaged) in each direction to Dale Mabry Avenue.
- Providing an EBS operating without any preferred treatment. The transit alternative is in turn subdivided into three subalternatives, each corresponding to a specific bus trip frequency.

In comparison to a fixed guideway transit mode, an EBS offers the benefit of minimizing capital cost and providing maximum flexibility. An EBS specifically targets work trips from suburban areas to downtown employment centers during peak-hour periods. It has the advantages of requiring lower overall population density, with relatively localized surburban development centers. An EBS promotes the convenience of transit to a new segment of the population, such as middle class surburban families. Furthermore, an EBS could be easily adapted to function as a feeder network for a future rail system or people mover.

The QA is not intended to replace the need for a comprehensive investment analysis. It focuses on one type of benefit: reduction in delay. The QA provides an appropriate short-term solution to a congested corridor. The Arterial Analysis Package (AAP) with its component programs, Signal Optimization Analysis Package (SOAP), Progression Analysis and Signal System Evaluation Routine (PASSER II), and Transit Network System (TRANSYT), are the software programs recommended to compute the overall delay for each alternative. The algorithms of the individual programs of AAP generate other measures of effectiveness, such as fuel consumption, percentage saturation, maximum queue, and number of stops. However, in order to reflect the public authorities' point of view, delay is the only measure considered. Both passenger-car user costs and farebox revenues are excluded from the evaluation model. In case a quick approach could not provide all the answers, other more comprehensive investment analyses should be performed. The objectives of the proposed method are to provide public authorities measures of how their investment performs with regard to savings in travel time and how alternatives are compared on this basis.

BACKGROUND

Whether to pay for new highways (constructing new roads or adding lanes to existing ones) or to invest in some type of transit system are subjects of a continuous debate taking place in the transportation community. In most cases they are complicated decisions involving a number of factors, all of which could not be assessed objectively. In addition to the direct costs (capital and operational) of each alternative, there are various effectiveness measures that need to be considered in the analysis; for instance, the impact on land development and economic growth, and increase in mobility and accessibility, and other nonmonetary effects of a social, environmental, and esthetic nature.

It is generally accepted that urban areas can grow only to certain sizes depending on the type of transportation system available. A relationship between transportation system, land use, and population densities is evident. New York City and Chicago population densities are not possible without heavy

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rail or rapid-transit systems. In other major cities, mobility is dependent on the existence of some form of transit mode. Rights-of-way in cities with high-density population tend to be expensive because of high costs of land, relocation expenses, business damages, and court fees. Consequently, an all-highway solution is rarely cost-effective. Furthermore, building more highway does not always solve the problem. It may simply shift the congestion to other links or nearby roads (traffic redistribution has its limitations). In several fast-growing cities, as in Florida, evaluating the feasibility of a transit system is a necessity to sustain healthy growth. Bus service exists in most large cities in Florida. Miami, Jacksonville, and Tampa have invested in fixed-guideway systems. Commuter rail in southern Florida and a high-speed rail linking major cities are in the final study stages.

Transportation planners are faced with two basic questions:

- At what stage is a transit system warranted?
- What short-term solution or intermediary step could be implemented to gain public support for raising adequate funds?

The first question has no simple answer. It is related to the area population density, growth pattern, trip generation, trip distribution, household average income, existing highway network and its degree of saturation during peak-hour periods, and transit attractiveness to potential users. This part of the study is beyond the proposed QA method. Trip generation and trip distribution analyses should be performed in prior stages as part of a comprehensive transportation planning study. Most of these data are normally available from the metropolitan planning organizations (MPOs). MPOs use mainframe computer programs to extrapolate many of these variables from the census data. However, the QA is independent of this analysis and could be applied regardless of the completion of the prior phase.

The proposed method is specifically designed to provide an answer to the second question. As explained earlier, an EBS (park-and-ride) is by far the most flexible, least expensive, and most appropriate intermediary transit mode. EBS expands transit ridership beyond the traditional user groups, such as transit-dependent, elderly, and low-income households. EBSs typically link suburban residential developments to downtown employment centers. They operate during peak hours on a fixed schedule from parking lots where commuters can safely and conveniently leave their vehicles. EBS users will avoid the frustration of driving on congested roads. Instead, they may comfortably read their newspapers or socialize with fellow passengers. Because an EBS serves work trips from a specific location on a fixed schedule, a first-time rider could well become a regular user. This highlights the importance of the quality of service, punctuality and reliability, parking convenience, and marketing techniques and incentive packages aimed toward employer and apartment managers. It is not uncommon to see developers, businesses, and churches donating land for the parking lots or perhaps sharing part of the construction costs.

OBJECTIVE

The objective of this paper is to outline and illustrate a quick approach for comparing the cost-effectiveness of highway and EBS investments. The sole concern is how each investment performs in relation to savings in travel time. Both alternatives are assumed to serve the same overall number of commuters, although a small percentage of induced demand will be added to the transit alternatives. The procedure is specifically adapted to an EBS because its impact on traffic is similar to that of recreational vehicles or trucks because there are no intermediate stops. Consequently, it is easily simulated using the AAP software. Even though the QA is developed for the EBS, other modes of bus operation could be analyzed if diligent engineering judgment is applied to the modeling process. Because all alternatives serve the same commuter volume with the same trip origin and destination patterns, the economic impacts on growth rate and land use are comparable for all alternatives. Neglecting these impacts in the analysis would not seriously affect the results.

As mentioned earlier, the proposed method is not intended to be a comprehensive investment analysis. Instead, it focuses on an important evaluation criterion: savings in travel time. The weakness of the approach is that it disregards the impacts of parameters other than delay (most of the factors omitted are of a subjective nature). On the other hand, congestion relief is generally the public authorities' primary concern, and delay is the best measure of the degree of congestion. The procedure consists of simulating traffic movement through the corridor for each alternative using AAP software. AAP will compute delays under several geometric, bus-trip frequencies and signal-timing conditions. The use of proven computer software (AAP) confers to the method a degree of conformity, consistency, reliability, and, best of all, a relatively fast and inexpensive execution tool. An additional advantage of the QA is that most of the data needed are already available for the purpose of signal-timing coordination, and the same data base could serve both purposes.

GENERAL APPLICATION

The procedure focuses on savings in travel time. Because AAP (TRANSYT/PASSER/SOAP) is the software used to compute delays, only users familiar with these programs and their delay algorithms and who understand the structure and reliability of each program's "measures of effectiveness" should apply the QA.

The method is extremely effective under two conditions: first, when the main intersections dividing the corridor operate during peak hours at a level of service of *D* or worse, resulting in long back-up traffic queues and, second, when the overall delay is mostly the result of inadequate capacity at signalized intersections. This is generally the case because the capacity of an intersection is only a fraction of that of a freeway. The reason for the QA effectiveness under similar conditions is simple and evident: TRANSYT and PASSER are the most relied on software programs for analyzing the operation of coordinated signalized intersections. NETSIM is too complicated and not compatible with a quick approach. Most planners target delay reduction rather than increase in capacity. When the service levels reach *D* or *F*, traffic volumes are at capacity and the flow is critical and unstable. Traffic progression could be stopped at any time. In similar situations, each increment of one vehicle in the traffic volume will have a significant and disproportionate impact on the overall traffic flow. Only computers have the computational capacity to identify the excess in traffic volume and measure its impact on the traffic flow, taking into account all the parameters affecting the operation of signalized intersections.

The effectiveness of the QA is in its ability to identify specifically those excess vehicles responsible for slowing the traffic flow. Furthermore, the QA evaluates the impact on the overall delay if commuters equivalent in number to the occupant of the excess vehicles would switch to a more convenient and efficient express bus mode. Under these circumstances the AAP program has a definite advantage in simulating traffic operation and computing the delay for various bus frequencies. The reason is that AAP takes into consideration the complex intersection operations such as left-turn maneuvers, shared-lane behavior, speed limits, lost time per phase, back-up traffic, oversaturation, progression, clearance, and so on. Furthermore, the perceived and objective improvement of heavily congested arterials is best measured in delay reduction rather than in increase in capacity. Consequently, measuring the effectiveness of each alternative in savings in travel time is reasonably justified.

In summary, the quick approach is very effective when used to analyze heavily congested arterial streets serviced by many signalized intersections. Usually, similar corridors are the ones considered for bus transit solutions. The objective is to reduce the overall number of vehicles during peak hours by increasing the passenger occupancy per vehicle. This is achieved through a complete removal of passenger cars from the corridor by providing a convenient and attractive bus service. A derivative benefit is in the reduction in number of downtown parking spaces needed. If operators of passenger cars simply choose to drive on other roads they might not always reduce traffic congestion but may simply shift the problem to nearby locations. The benefits of traffic redistribution are limited in heavily congested networks. If the EBS is successful in attracting a reasonable number of commuters, this could result in a dramatic improvement in the overall level of service.

Another important advantage of using a computer program to compute delay is the simplicity with which various sensitivity analyses could be performed. Once the data base is established, the bus alternative could be evaluated for various bus-trip frequencies and occupancy ratios to determine the optimal situation.

LIMITATIONS

The QA suffers from the limitations inherent in the AAP individual programs. Situations like nonsignalized intersections, intersections with more than four legs, alignment, ramps, exits, interchanges, oversaturation, pedestrians, right-lane turns, and so on, could adversely affect the validity of AAP simulations. Although AAP is capable of modeling these cases, it is feasible only at a cost of reduced accuracy. Furthermore, AAP Release 2 runs TRANSYT-7F and PASSER 84. It lacks the potential of mapping right turns and accounting for specific left-turn protection modes. These are important factors in optimizing the timings and in computing delays. The most recent release of AAP Version 3 (Fall 1988) is upgraded to include several new applications, such as updates to the component SOAP and TRANSYT programs, and an addition to a right card to allow more correct modeling of all turning movements using TRANSYT-7F Release 5. Finally, the use of the newest version of AAP to generate data and run individual programs does not permit the use of specific features like side friction factors or mid-block entry volumes. If the situation requires, it is best to use the individual programs or perhaps EZ-TRANSYT.

METHODOLOGY

The QA combines the advantages of simplicity, conformity, and objectivity. AAP simulation for each alternative is achieved by following the same general optimization process. The procedure consists of the steps described in the following subsections.

Step 1

Step 1: The use of AAP (PASSER and TRANSYT) to optimize the traffic operation and compute delay under existing conditions.

The optimization procedure should not be any different from the steps used to optimize signal timing using AAP. It consists of first applying TRANSYT to model the traffic operation with the existing timings. PASSER is then used to maximize the bandwidth by selective phasing optimization as indicated by the time-space diagram. Afterward, the best phasings are selected and PASSER is once again applied to optimize the cycle length and the timings. It is then necessary to input PASSER's phasings and timings into TRANSYT and check for any improvement over the initial run. Finally, TRANSYT will be used to optimize the cycle length and timings.

The results should always be checked by examining the primary and secondary bandwidths on the time-space diagram and the traffic progression on the progression plots. In some cases it is beneficial to start by using SOAP on critical intersections. Analysts should respect the local stated policies for minimum green, clearance, all red for pedestrian, and so on. If additional restrictions or requirements are applicable, they should be taken into consideration.

Step 2

Step 2: Use of AAP to simulate delay after geometric improvement (adding one or more lanes).

The second step consists of simulating the traffic flow in the corridor after the geometric improvement (adding one or more lanes to the main street). If adding some left-turn lanes is part of the improvement, they should be accounted for. AAP optimization will be achieved following the same procedure outlined in Step 1.

Step 2 could consist of multiple optimizations, depending on the number of geometric alternatives considered. Simulating a managed (restricted lane) geometric alternative is feasible if the right data are available (estimates of HOV lane volumes and average occupancy per vehicle).

Step 3

Step 3: Use of AAP to simulate delay under various express bus transit frequencies (optimize the number of buses needed).

The third step simulates the overall delay for the bus transit cases. At this stage several assumptions must be made. First, the peak-hour volume is assumed to serve primarily work-trip purposes (a reasonable assumption in heavily congested streets). Second, the work-trip volume is considered to be a finite number with limited elasticity. The third assumption is related to the validity of the models used to forecast trip generation, relative bus occupancy, traffic growth projection, induced demand estimation, and other forecasting parameters. Understanding these assumptions is important because the model transfers a number of commuters from passenger cars to the EBS, based on a realistic bus-car occupancy ratio. In summary, all the assumptions are reduced in the model to establish a realistic bus occupancy ratio for the EBS as a function of bus-trip frequency. The average occupancy of a car is a measure normally available at the city planning offices. In any case, it is generally accepted that ridership for new transit systems builds up over a period of time.

Once a reasonable bus-car occupancy ratio is determined from field studies or from referring to comparable systems, a number of cars will be taken off the highway and replaced by a number of buses determined by the occupancy ratio equation. In Step 3, several bus-trip frequencies should be considered to determine the optimal effectiveness of the system (most delay reduction per unit investment). However, it is logical that the real occupancy of each bus should decrease when the trip frequency increases, although widely dispersed parking lots could be served. For each case, AAP will simulate the traffic movement under the new condition and generate various measures of effectiveness. Although the total number of vehicles using the network will change at each modal split considered, the overall number of commuters will remain constant, except for a small percentage of induced travel (new vehicles diverted from other routes and attracted by the improvement in the level of service).

Step 4

Step four: Cost-benefit analysis.

Cost-benefit analysis is achieved by computing the ratio of the benefit to the cost. As explained earlier, the benefit for all alternatives is measured in savings in travel time. The alternative of Step 1 is the base condition. It has zero cost and zero benefit. The costs of the alternatives in Step 2 (geometric improvement) are subdivided into costs of construction; rights-of-way, including land cost, relocation expenses, business damages, and court fees; law enforcement; and maintenance. The costs associated with the bus transit alternatives of Step 3 are separated into capital and operational expenses. Capital cost includes the cost of the buses needed; of parking lots (average cost per space by number of spaces); and of the infrastructure for management, storage, and maintenance. Operational costs include management, maintenance, fuel, and overhead.

Right-of-way costs might be obtained from the appropriate department of the city government. Construction costs for lanes and parking lots are normally updated by the city public works department. Finally, capital and operational costs for the EBS could be obtained from the local transit agency if any exists. If some of the data are still missing, county or state agencies might provide this information. Finally, FHWA and UMTA, of the U.S. Department of Transportation (DOT), and the American Public Transit Association (APTA) publish annual statistics on a wide range of data. They are good references for providing average or state figures if nothing else exists.

The benefit of each alternative is determined by multiplying the simulated time savings, determined by AAP, for each improvement with an accepted dollar value of an hour saved. Most public and private references use a value between minimum wage and $8/hr saved. The unit value must be updated using the consumer price index. However, if the purpose of applying the QA is simply to rank the alternatives, the result is unaffected by the dollar value associated with a unit time saved. Savings of travel time for each alternative are computed by comparing the overall delay to that simulated for alternative zero or base case.

The cost-benefit ratio for each alternative is found by dividing the dollar value of the time saved per year (2 peak hours per day, 300 days per year) by the total annualized cost for capital and operational expenditures. The service lives used to annualize capital costs are 12 years for buses, 20 years for parking and roads, and 100 years for rights-of-way. A discount rate acceptable to public planners should be used. It is preferable to perform the analyses for low-, average-, and high-discount-rate values.

STUDY CASE

Dale Mabry Avenue is selected to illustrate the application of the QA. It is one of the most congested arterials in Tampa, Florida. Data on the intersections' geometry and traffic volumes at peak hours were provided by the city traffic engineers.

First, PASSER was used to determine the optimal phasings. Then TRANSYT was used to evaluate PASSER results and perform the final optimizations. The delay values used to compute the benefits for each alternative are the ones simulated using TRANSYT cycle and timing optimizations. T-0 corresponds to TRANSYT optimization for the existing condition or alternative zero. T-1 represents TRANSYT optimization results for the geometric improvement case, which consists of adding one through lane on each direction of the avenue. T-2 corresponds to TRANSYT optimization for the first bus alternative, which consists of providing 20 bus trips per peak hour with a bus-car occupancy ratio of 28 to 1.15 passengers. T-3 corresponds to TRANSYT optimization of the second bus alternative, which consists of adding 30 bus trips per peak hour with a bus-car occupancy ratio of 25 to 1.15 passengers. Finally, T-4 corresponds to the optimization of the third bus alternative, which consists of providing 40 bus trips per peak hour, with an occupancy ratio of 22 to 1.15 passengers. The average passenger car occupancy ratio measured in Tampa is 1.15 passengers per car.

Each bus costs about $140,000. It has a seating capacity of 48 passengers (plus 25 standees). The bus service life is 12 years with a zero salvage value. Parking costs are computed using a unit cost of $3,000 per space. Bus operation costs are calculated considering a unit cost of $2.50 per revenue-mile. These values were provided by the Hillsborough Area Regional Transit (HART) servicing the Tampa area. The road section considered for improvement is 6 mi. long. The right-of-way cost is about \$15/sq ft. Construction costs are, on average, \$900,000/lane-mi. Law enforcement is around \$6,000/lane-mi, and the maintenance cost is approximately \$5,500/lane-mi. These figures were supplied by various city departments in Tampa.

For the bus alternatives, an induced traffic demand equivalent to 15 percent of bus ridership is assumed to be diverted from other routes because of the improvement in the level of service. Furthermore, not all the EBS users are presumed to be diverted from the passenger car mode; 15 percent of them will be considered as new commuters attracted by the system. Consequently, transit alternatives are expected to carry a total number of commuters equivalent to the geometric alternatives plus 30 percent of the EBS ridership. The remaining assumptions used in the study case are that an hour delay costs \$3.35 (minimum wage) and the farebox revenues are about 30 percent of the operational costs (HART figure). The revenues from the bus fares are subtracted from the transit costs because they reduce the public subsidy.

The cost-benefit ratios are computed a second time for the alternatives considering the loss in potential revenues from the gas tax as an additional cost for the bus alternatives. These ratios are computed separately because, although a clear loss in income from the gas tax will occur, the monetary benefit may be more than offset by adverse environmental impacts like pollution. Whether to account for the gas-tax-revenue losses or not is left to the judgment and discretion of the QA user.

The cost-benefit analysis and the results of the computer optimizations are included in the tables. Table 1 summarizes the AAP simulations for delay. The costs for the geometric improvement are given in Table 2, and the costs for the transit alternatives are given in Table 3. The cost-benefit analysis presented in Table 4 shows the bus alternative with a trip frequency of 20 round trips per day to have the highest cost-benefit ratio. It provides the highest revenue by unit investment. However, if the cost-benefit ratio rather than the relative ranking of alternatives is the goal of the planner, an incremental cost-benefit analysis should be performed.

CONCLUSION

The proposed quick-response method is a simple and effective procedure to compare the effectiveness of widening a major arterial street operating at a poor level of service or to provide an express bus service (park-and-ride). Highway and transit are costly investments; the QA provides a quick and inexpensive tool to perform a preliminary evaluation. Furthermore, most of the data required are normally available and constantly updated for the purpose of signal-timing coordination. Most of the cost figures needed should be available at the local public offices. As a last resort, the user may refer to publications of a number of private, state, and federal agencies, such as FHWA, UMTA, and APTA. Finally, because computer modeling is needed to simulate traffic delays and not to optimize the signal timings, approximate input data are more tolerable.

It is important to understand the way traffic delays are

TABLE 1 SUMMARY OF AAP RESULTS

RUN # (AAP)	DESCRIPTION OF ALTERNAT.	TOTAL DELAY (VEH X HR)	Ave. DELAY (SEC /VEH)	STOPS		FUEL CONS. (GALLONS)	CYCLE (SEC)
				TOTAL	%		
T-0	120 SEC CYCLE	1641	113.0	30435	58	1971	120
T-1	+ 2-Lane OPT	907	62.4	28791	55	1416	120
T-2	+ 20B/H OPT	958	79.3	27351	63	1332	120
T-3	+ 30B/H OPT	801	71.3	25623	63	1332	120
T-4	+ 40B/H OPT	722	68.1	22856	60	1049	120

Alt 0: do nothing

Alt 1: add 2 lanes, one in each direction

Alt 2: provide 20 buses (28 pass. per bus, 15% induced demand)

Alt 3: provide 30 buses (25 pass. per bus, 15% induced demand)

Alt 4: provide 40 buses (22 pass. per bus, 15% induced demand)

OPT: computer optimization (TRANSYT)

B/H: bus trip per hour

TABLE 2 COSTS FOR GEOMETRIC IMPROVEMENT

ALT. #	ITEM	CAPITAL COST	SERVICE LIFE	ANNUAL COSTS
ALT 1	R-O-W	$14,256,000	100 Yrs	($1,425,000)
	Const.	$10,800,000	20 Yrs	($1,269,000)
	Maintenance			($66,000)
	Law Enforcement			($72,000)
	TOTAL ANNUALIZED COST =			($2,832,000)

RIGHT OF WAY: $15/sq.ft.x(2x15ft)x6milesx5280ft/mi= $14,256k

CONSTRUCTION: 6 miles x 2 lanes x $900k/lane-mile = $10,800k

LAW ENFORCEMENT: $6,000 per lane-mile

MAINTENANCE: $5,500 per lane-mile

DISCOUNT RATE: 10% per year

TABLE 3 COSTS FOR TRANSIT IMPROVEMENTS

ALT #	ITEM	CAPITAL COST	SERVICE LIFE	ANNUAL COSTS
ALT 2	BUS:	$1,400,000	12 Yrs	($205,000)
	PARKING:	$1,680,000	20 Yrs	($197,000)
	OPERATION:			($126,000)
	TOTAL ANNUAL COSTS =			($528,000)
ALT 3	BUS:	$2,100,000	12 Yrs	($308,000)
	PARKING:	$2,250,000	20 Yrs	($264,000)
	OPERATION:			($189,000)
	TOTAL ANNUAL COSTS =			($761,000)
ALT 4	BUS:	$2,800,000	12 Yrs	($411,000)
	PARKING:	$2,640,000	20 Yrs	($310,000)
	OPERATION:			($252,000)
	TOTAL ANNUAL COSTS =			($973,000)

BUS COST = $140,000 x # Trips/PH / 2 (2 Trips per Peak Hour)

BUS OPERATION = 2*#Bus/PH x $2.5/rev-mile x 6miles x 300dayx70%

BUS OCCUPANCY (45 SEATS CAPACITY):
Alt.2: 20 buses/peak-hour: 28 passengers/bus (62%occupancy)
Alt.3: 30 buses/peak-hour: 25 passengers/bus (55%occupancy)
Alt.4: 40 buses/peak-hour: 22 passengers/bus (49%occupancy)
85% Would Have Used Dale Mabry Avenue

PARKING COST: $3,000 per space

DISCOUNT RATE: 10% per year

TABLE 4 COST-BENEFIT ANALYSIS

ALT #	TIME SAVING (TS) (VEH X Hr)		BENEFIT / Yr (TSx$3.35x300x2)	COST / Yr ($)	BEN./COST. ($)
ALT 0	0		0	0	0
ALT 1	734	45%	1,475kx2= 2,951k	2,832k	1.04
ALT 2	683	42%	1,373k	528k	2.60
ALT 3	840	51%	1,688k	761k	2.22
ALT 4	919	56%	1,847k	973k	1.90

**** BEST = ALT 2 (20 Bus-Trip / P.H.) ****

For Alt.# 1 (adding 2 lanes) traffic delay will be reduced beyond the peak hour periods. Assuming peak hour traffic accounts for 50% of the daily delay, the benefits for this alternative is multiplied by a factor of 2.

If the loss in potential gas-tax revenues are to be considered as an additional cost for the bus alternatives, the respective benefit cost ratio would be as following:
Alt 1 : 1.04 Alt 2 : 1.210 Alt 3 : 1.08 Alt 4 : 1.04
(Alt# 2 is still the case with the highest benefit to cost ratio)

To optimize the benefits, an incremental cost benefit analysis should be performed.

generated, the impact of oversaturation, and the validity and reliability of computer solutions under specific conditions. It is always advisable to check the results of the existing case in the field (measure peak-hour delays). If the delays measured in the field are compatible with the computer output for the initial case, the delay simulations for the alternative cases will be valid also because the traffic operation after improvement is less critical. Computer modeling is, in general, more accurate for less critical traffic flows.

To summarize, the quick-response method is not intended to replace the need for a comprehensive investment analysis. It is just one indicator of how public investments perform toward reducing traffic delay. In many cases, congestion relief is the main objective of transportation planners.

The procedure is, therefore, most effective when dealing with major urban arterial streets operating at a poor level of service as a result of inadequate intersection capacities. Typically, rights-of-way on similar streets for additional lanes are quite expensive, which makes transit systems more attractive. The EBS is a transit mode requiring minimum capital cost and providing maximum flexibility. Furthermore, an EBS is most convenient for a new type of transit users—suburban middle class families.

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Panel Survey Approach to Measuring Transit Route Service Elasticity of Demand

Eric J. Miller and David F. Crowley

This paper presents the results of a pilot test of a panel survey procedure designed to determine transit service elasticities of demand under a range of operating and demographic conditions. This procedure consists of surveying a randomly selected panel of potential transit users within a given study area, both before and after a transit service change occurs, and then using the observed changes in transit usage by this panel of users to impute service elasticity characteristics. A total of 76 panelists were recruited from existing users of the test route by interviewers stationed at transit stops located within the study area, representing a net recruitment success rate of 72 percent. Each panelist was required to complete "trip record sheets" for 2 weeks before and 2 weeks after the service change. The attrition rate over the course of the survey period with respect to panelist participation in the survey was quite low, with 75 percent of the panel (57 out of 76) still active in the panel after the 4 record-keeping weeks. Ridership on the test route declined by 17 percent (1.3 trips per week per person) in response to a 50 percent increase in peak-period headway (and up to a 100 percent increase in off-peak headways). 53.8 percent (0.7 trips per week per person) of this ridership loss, however, shifted to alternative routes rather than to competing modes, resulting in a net loss in system patronage of 0.6 trips per week per person or 6.8 percent of the "before" period ridership in the study area. These changes translate into an aggregate headway elasticity on the test route of approximately −0.4, whereas the elasticity of total transit ridership in the service area with respect to headway changes on the test route is of the order of −0.1.

"Service elasticity of demand" refers to the elasticity of transit ridership with respect to changes in transit service headway (or frequency). The relevance of service elasticity of demand to transit planning activities is clear: one of the most common actions available to a transit operator in its attempts to improve service efficiency and effectiveness is to alter service frequencies on selected routes. It follows directly that the better the likely responses of the traveling public to such changes are understood, the more effectively such changes can be designed and implemented. The purpose of this paper is to describe an experimental procedure for determining service elasticities of demand and to present the results of a "pilot test" of this procedure. The procedure consists of surveying a randomly selected panel of potential transit users within a given study area, both before and after a transit service change occurs, and then using the observed changes in transit usage by this panel of users to impute service elasticity characteristics.

BACKGROUND

Despite the importance of service elasticity of demand to transit planning, little solid, quantitative service elasticity data are available. Mayworm et al. summarize the empirical experience in North America and Great Britain as of 1980 and construct average bus demand elasticities with respect to headways of −0.37 for peak periods (±0.19, based on three cases), −0.46 for off-peak periods (±0.26, based on nine cases), and −0.47 for all-hours service (±0.21, based on seven cases) (*1*). Disaggregate mode-choice models also provide some insight into the sensitivity of travelers to transit headways in that they indicate that transit out-of-vehicle travel time (which depends, among other factors, on route headways) is typically weighted by travelers 1.5 to 3.5 times more heavily than in-vehicle travel time (*2,3*). Finally, various manuals on transit ridership analysis discuss the use of service elasticities without providing strong empirical evidence concerning relevant elasticity values to use, beyond quoting the Mayworm et al. results cited here (*4,5*).

Three major reasons exist for this relative lack of insight into transit service elasticities. The first is that—unlike fare changes, which are systemwide in their effect—service frequency changes are applied on a route-by-route basis. Thus, a single, systemwide elasticity is not observable, nor is it even a very meaningful concept. Second, the accurate measurement of "before" and "after" ridership at the route level is a very complex and expensive task, principally because of the relatively large temporal variations that exist in transit ridership at the route level, as well as uncertainty concerning how long it takes route ridership levels to adjust to a change in service frequency. And, third, service frequency changes are typically made in an "uncontrolled environment" within which other service changes may be simultaneously introduced, the impact on parallel or cross routes is not monitored, and changes in route ridership on "control" routes are not observed. The result in such cases is that even if a change in ridership on the route in question can be observed with reasonable accuracy, the proportion of this change that is a net change in *system* ridership and, of this, the amount attributable to the service frequency change, is difficult to determine.

These observations clearly indicate the need for a carefully designed experimental procedure, in which as many factors affecting ridership as possible are either controlled (i.e., held

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constant) or explicitly measured (so that the effect of changes in these factors can be explicitly accounted for), as well as in which all types of ridership responses (mode shifts, route shifts, changes in trip rates, etc.) are directly measured.

PANEL SURVEY APPROACH

One obvious approach to measuring changes in a transit route's ridership is to conduct a set of ridership counts before and after the service change. This approach, however, is extremely limited in the information that it generates, very labor-intensive if sufficient observations for statistical reliability are to be gathered, and subject to a wide variety of uncontrolled factors that may well confound the results obtained. The net result of these limitations is that the riding count approach is neither a very reliable nor cost-effective approach for measuring transit service elasticities [for further discussion of this issue, see Miller (*6*)].

A second approach involves the random selection of a representative panel of residents within the test route catchment area and monitoring the before and after usage levels of the panel members through the use of a diary survey. Relative to the ridership count approach, the panel survey approach has the following advantages:

- The survey cost-effectively collects travel information for all service periods.
- The survey readily collects information concerning mode and transit route for each trip made. Hence, both route-shift and mode-shift effects can be identified.
- A wide range of socioeconomic characteristics of each trip maker can be obtained. Hence, differences in elasticities among different groups of people can be examined.
- Further, because each individual within the panel is explicitly identified and "tracked" during the test period, considerable control over the test is possible. In particular, virtually every factor affecting transit route usage can be controlled in the panel survey approach. In addition, population movements into and out of the test area will not have an impact on the panel survey results.

The panel survey approach thus provides controlled and detailed information concerning travel responses to a transit service change. The only major limitation of the approach is that it depends on each panel member recording his or her trip information over a potentially lengthy test period. There are clearly limits, however, in people's willingness to fill out questionnaires over long time periods. The success of such a panel survey depends on simplifying the respondents' task to make their participation over an extended period as painless as possible. In addition, recruitment and sustained commitment depend on the provision of appropriate incentives to each panelist to join the panel in the first place and then to continue to participate fully in the panel throughout the course of the survey. In this study two such incentives were used:

- A lottery ticket to encourage participation in the initial interview at the transit stop.
- Financial incentives to encourage continued participation in the survey. This involved entering all active panel members in a weekly cash lottery.

PANEL SURVEY DESIGN AND EXECUTION

The Mt. Pleasant Road trolley bus route (Route 74) in the City of Toronto was chosen as the study test route (see Figure 1). This route was viewed as a nearly ideal candidate for the pilot test since it had long been considered a candidate for service reduction, independent of the needs of this study; it has a well-defined, almost entirely residential, catchment area; and the resident population of the study area is relatively homogeneous. Based on Toronto Transit Commisssion analysis of the route's service requirements, the following changes in service headways were implemented on October 18, 1987, as part of a regular board period change:

- Peak-period headways were increased 50 percent from 10 to 15 min.
- Early evening (7 to 9 p.m.) headways were increased 100 percent from 15 to 30 min.
- Midday and late evening headways were left unchanged at 15 and 20 min.

The survey panel members were recruited by interviewers located at test route stops who intercepted passengers while they waited for the arrival of a bus. Panel recruitment occurred during 3 days of the week immediately before the first week of the survey. A total of 78 out of 121 persons interviewed (64 percent) agreed to participate in the survey. Many of the "refusals" recorded actually represent a failure to complete the interview before the next bus arrived. If these incomplete interviews are subtracted from the total (along with people who were rejected for reasons such as they knew that they would soon be moving out of the study area), then the acceptance rate becomes 78 out of 108 or 72 percent.

Each panel member was given a booklet at the time of recruitment that contained "trip record sheets" for each weekday for the 4 weeks that the panel member was to record his or her trips made to and from home, along with instructions on how to fill out these sheets. Each trip record sheet was designed so that the panelist merely had to "tick" the box corresponding to the time of day, trip purpose, and trip mode for each trip that began or ended at home. Figure 2 provides an example of one side of a trip record sheet for trips beginning at home for Monday, November 9, 1987 (the other side of this sheet contained a similar form for recording the trips made that ended at home for this same day). The 4 weeks for which trip records were to be kept began on Monday, September 28, October 5, November 9, and November 16, respectively, with the first 2 weeks occurring before the Mt. Pleasant route service change on October 18, and the second 2 weeks occurring after this change. The timing of the 2 "before" weeks was chosen so as to avoid the Thanksgiving holiday Monday (October 12), and the timing of the 2 "after" weeks was chosen to provide as long an "adjustment period" as possible (in this case, 3 weeks), without overly extending the survey duration. Four addressed, stamped envelopes were provided to each panelist, and the panelist was requested to mail the five trip record sheets for each week of the survey in one of these envelopes at the end of each week of recording.

Each panelist was contacted by telephone once for each of the 4 survey weeks. The objectives of these contacts were to ensure that the panelist was actively filling out the survey

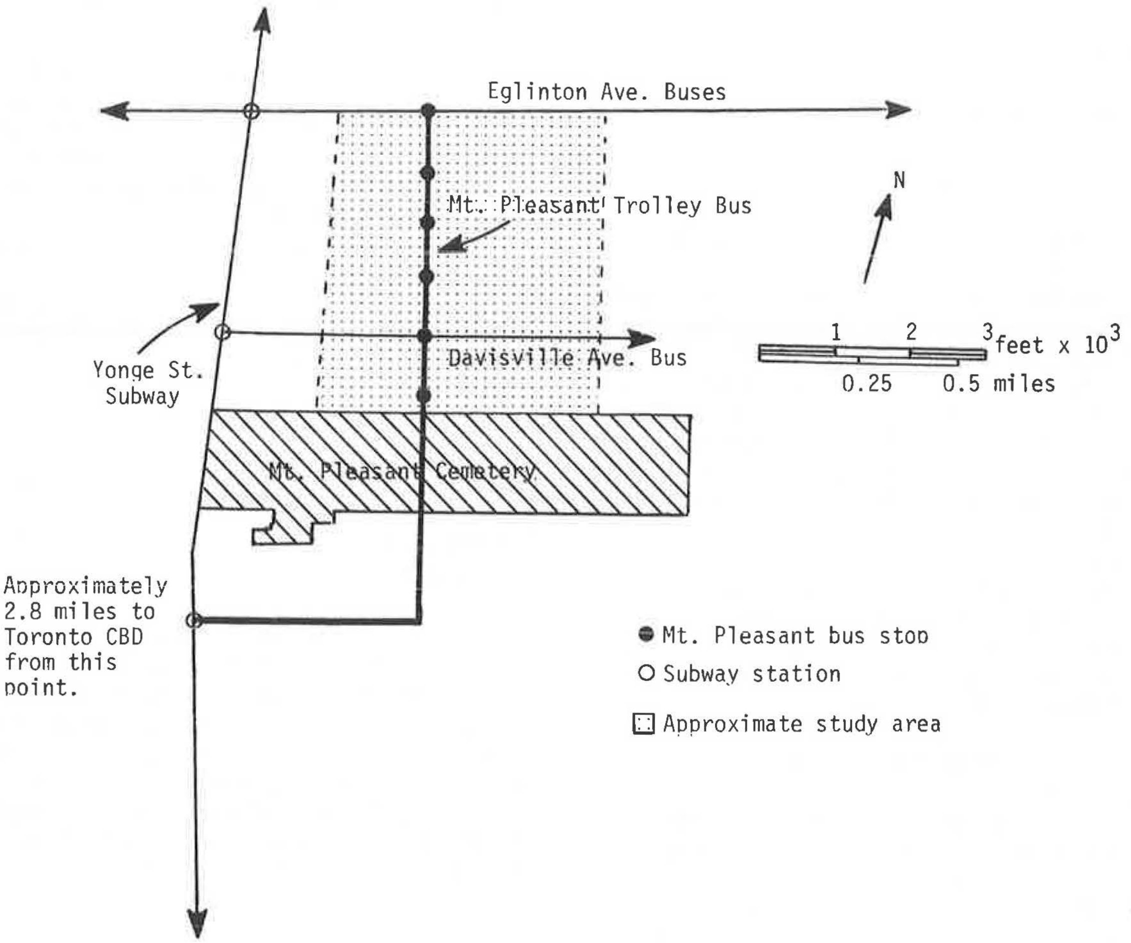


FIGURE 1 Study area.

forms, to obtain additional information about the panelist's socioeconomic characteristics, and to ascertain whether anything unusual happened to the panelist during the week (e.g., was sick or away on business) or whether anything had happened to alter the panelist's characteristics (e.g., changed jobs) that would have affected the panelist's trip-making propensities. All panelists who reported that they were filling out the trip record sheets for the given week were eligible for a cash lottery. Six winners were selected from this group each week and sent checks for the amount won. One $50 and five $10 prizes were awarded each week.

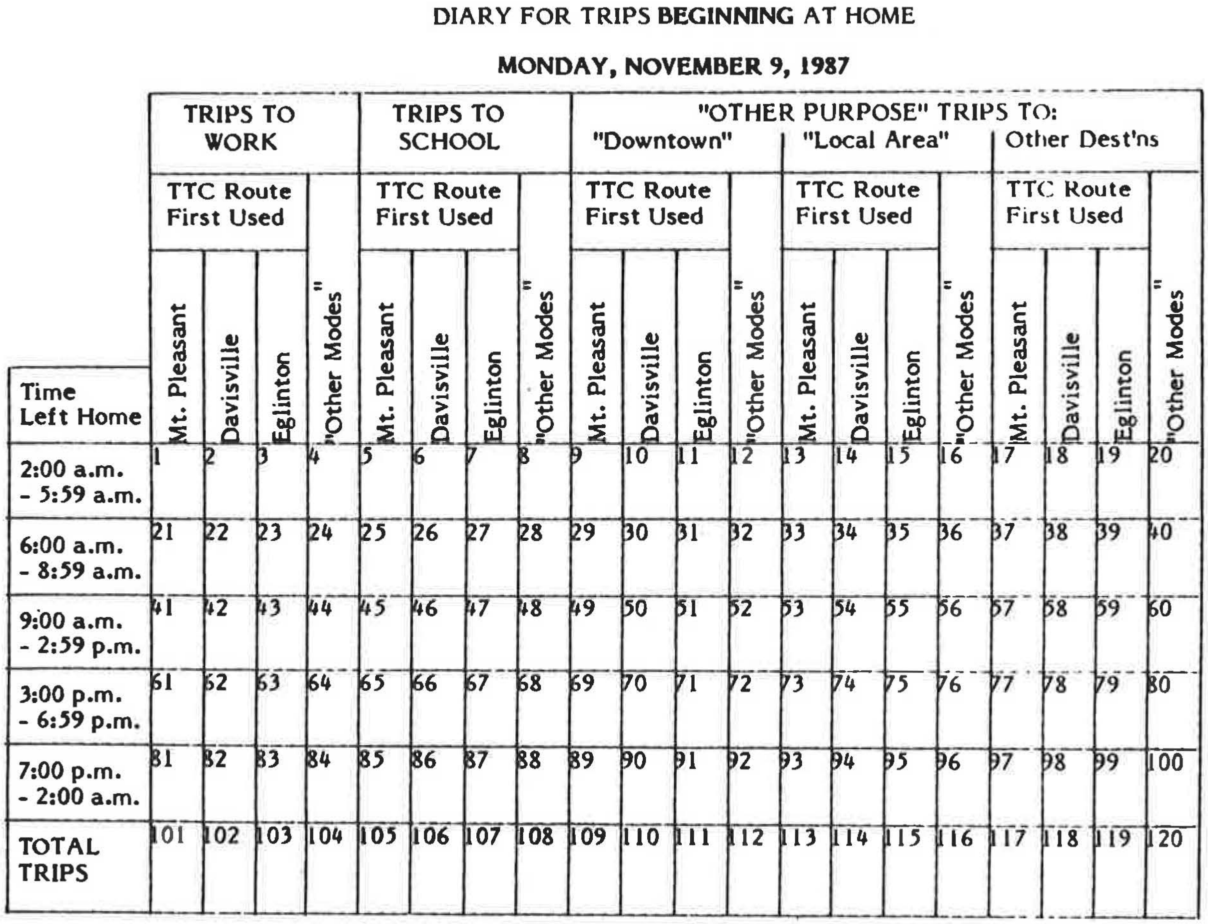
The overall completion rate for the 4 weeks of the survey is 75 percent. Subtracting those panelists who dropped out because of sickness, moving out of the neighborhood, and changing jobs, the completion rate is 57 out of 70 or 81.4 percent. Further, if one focusses on those panelists who could be contacted by telephone during the course of the survey, the completion rate is 55 out of 61 or 90.2 percent. In contrast, the completion rate among those panelists who could not be contacted by telephone (either because they refused to provide a number or the number was recorded incorrectly) was 2 out of 8 or 25 percent.

ANALYSIS OF SURVEY RESULTS

Table 1 presents a summary of the trip-making behavior of the panel over the duration of the survey. It shows the average one-way (i.e., to or from home) trips per week per person, by mode, for each week of the survey, as well as for the 2 "before" weeks (Weeks 1 and 2) and the 2 "after" weeks (Weeks 3 and 4) combined. These averages represent "net" trip rates, in that days or weeks in which "unusual" events (e.g., sickness, vacation, etc.) resulted in "unusual" trip patterns have been factored out, thus allowing variations in observed trip rates to be unambiguously attributed to the change in transit service. Average mode splits are also shown.

Two key points to note from this table are

- Average weekly rides per person on the Mt. Pleasant bus declined from 7.5 to 6.2 trips per week (a 17 percent decrease). This translated into a decline in the Mt. Pleasant route's modal share from 70.5 percent to 61.7 percent (a 12.5 percent decrease in modal share).
- The percentage of all trips made by panelists on any transit route, however, declined by only 1.7 percent, from



DIARY FOR TRIPS **BEGINNING** AT HOME

MONDAY, NOVEMBER 9, 1987

	TRIPS TO WORK				TRIPS TO SCHOOL				"OTHER PURPOSE" TRIPS TO:											
									"Downtown"				"Local Area"				Other Dest'ns			
	TTC Route First Used				TTC Route First Used				TTC Route First Used				TTC Route First Used				TTC Route First Used			
Time Left Home	Mt. Pleasant	Davisville	Eglinton	"Other Modes"	Mt. Pleasant	Davisville	Eglinton	"Other Modes"	Mt. Pleasant	Davisville	Eglinton	"Other Modes"	Mt. Pleasant	Davisville	Eglinton	"Other Modes"	Mt. Pleasant	Davisville	Eglinton	"Other Modes"
2:00 a.m. - 5:59 a.m.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6:00 a.m. - 8:59 a.m.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
9:00 a.m. - 2:59 p.m.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
3:00 p.m. - 6:59 p.m.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
7:00 p.m. - 2:00 a.m.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
TOTAL TRIPS	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120

FIGURE 2 Sample trip record sheet.

TABLE 1 AGGREGATE TRIP RATES AND MODE SPLITS

	Week 1	Week 2	Week 3	Week 4	Weeks 1 + 2	Weeks 3 + 4
Weekly trips						
All modes	11.0 (2.9)	10.3 (3.1)	10.0 (2.2)	10.2 (2.8)	10.6 (3.0)	10.1 (2.5)
All transit	8.9 (2.8)	8.6 (2.3)	8.2 (2.8)	8.2 (2.8)	8.8 (2.6)	8.2 (2.8)[a]
Mt. Pleasant bus	7.7 (3.3)	7.2 (2.9)	6.3 (3.1)	6.0 (3.4)	7.5 (3.1)	6.2 (3.2)[a]
No. of observations	58.0	52.0	48.0	45.0	110.0	93.0
Mode splits (%)						
Transit/Total	81.3 (24.0)	84.2 (22.4)	82.1 (26.8)	80.5 (25.4)	82.7 (23.5)	81.3 (26.3)
Mt. Pleasant/Tot	70.5 (30.2)	70.4 (29.9)	63.7 (31.0)	59.5 (33.4)	70.5 (30.2)	61.7 (32.4)[a]
Mt. Pleasant/Tr.	86.6 (21.8)	83.6 (23.6)	77.6 (26.8)	73.9 (30.4)	85.2 (22.8)	75.8 (28.8)[a]
No. of observations (1 + 2)	58.0	51.0	48.0	44.0	109.0	92.0
No. of observations (3)	58.0	51.0	46.0	44.0	109.0	90.0

[a] Statistically significant at 95% confidence level.

82.7 percent to 81.3 percent. Hence, the majority of the loss in Mt. Pleasant ridership represents a "route shift" to competing transit routes, rather than a "mode shift" to competing modes.

Table 2 presents "before" and "after" trip summary information for workers and students in one group and "others" in the other. Nonworkers in this sample (predominantly seniors) travel less than workers and their modal choices are virtually invariant between the "before" and "after" periods. This latter result presumably reflects the lack of flexibility that nonworkers have in their choice of both modes and routes. That is, this group generally appears to be truly "captive" to transit, and hence its only response to reduced service is either to continue to use transit despite the service reduction or else to not make the trip. This latter option may be reflected in a "before" to "after" trip rate reduction of 1.4 trips per week

TABLE 2 AGGREGATE TRIP RATES AND MODE SPLITS, WORKERS AND STUDENTS VS. NONWORKERS/STUDENTS

	Workers and Students		Nonworkers/Students	
	Weeks 1 + 2	Weeks 3 + 4	Weeks 1 + 2	Weeks 3 + 4
Weekly trips				
All modes	10.8 (2.8)	10.3 (1.9)	9.7 (4.7)	8.3 (4.6)
All transit	9.0 (2.5)	8.5 (2.6)	7.0 (3.2)	6.1 (3.3)
Mt. Pleasant bus	7.8 (3.1)	6.5 (3.2)[a]	5.0 (2.7)	4.3 (2.5)
No. of observations	98.0	81.0	12.0	12.0
Mode splits (%)				
Transit/Total	83.8 (23.1)	82.2 (26.8)	72.3 (25.7)	73.7 (21.5)
Mt. Pleasant/Tot	72.6 (29.5)	62.7 (32.5)[a]	51.1 (31.2)	52.5 (31.6)
Mt. Pleasant/Tr.	86.6 (22.5)	76.3 (29.0)[a]	70.6 (21.1)	71.2 (28.3)
No. of observations (1 + 2)	97.0	81.0	12.0	11.0
No. of observations (3)	97.0	79.0	12.0	11.0

[a] Statistically significant at 95% confidence level.

TABLE 3 SERVICE ELASTICITIES

		Elasticities[a]		
Trip Purpose	Time Period	Mt. Pleasant	Total Bus	All Modes Transit
Work/ school trips[b]	All periods	−0.40	−0.06	0.00
Non-work/ school trips[c]	All periods	−0.40	−0.40	−0.29
All purposes	Peak periods	−0.47	−0.15	−0.10
All purposes	Off-peak	−0.29	0.00	−0.10

[a] Computed using the formula $e_{Dx} = \{(D_2 - D_1)/(D_2 + D_1)\}\{(x_2 + x_1)/(x_2 - x_1)\}$, where $e_{Dx} = \{\Delta D/D_0\}/\{\Delta x/x_0\}$; ΔD = change in demand level, equal to $(D_2 - D_1)$; D_1, D_2 = "before" and "after" demand levels, respectively; D_0 = "reference" demand level, equal to $(D_2 + D_1)/2$; Δx = change in headway, equal to $(x_2 - x_1)$; x_1, x_2 = "before" and "after" headways, respectively; and x_0 = "reference" headway, equal to $(x_2 + x_1)/2$.

[b] Given that a majority of work/school trips occur during the morning and afternoon peak periods, it is assumed that the relevant headway for computing work/school trip service elasticity is the peak-period headway.

[c] It is assumed that the relevant headway for computing non-work/school trip service elasticity is the early evening period headway. This time period is clearly the relevant time period for workers and students, the majority of whom are away from home at work or school during the rest of the day. This time period would also appear to be the relevant one for non-workers/students given that most round trips by panelists in this group either began or ended during this time period.

for nonworkers (a 14.4 percent reduction) compared with a 0.5 trips per week reduction for workers/students (4.6 percent).

Further analysis of the worker/student group indicates that nonwork/school travel for this group is far less dependent on transit than are work/school trips, with an aggregate "before" modal split of only 48.6 percent versus 88.3 percent for work/school trips. Further, nonwork/school travel is far more sensitive to the change in transit service, exhibiting a 43.2 percent decline in the Mt. Pleasant route's modal share (36.8 percent to 20.9 percent), compared with a decline of 14.0 percent (87.6 percent to 76.7 percent) for work/school trips. Finally, the shift in nonwork/school trip making generally involves a shift to other modes, because the loss of 0.3 trips per week (0.5 to 0.2) on the Mt. Pleasant route translates directly into an overall loss of 0.3 transit trips per week. The shift in work/school trips, however, is largely a route shift, in that the decline of 1.1 Mt. Pleasant route trips per week (7.4 to 6.3) results in an overall decline in transit usage of only 0.2 trips per week (8.4 to 8.2).

Table 3 presents estimates of arc elasticities for Mt. Pleasant bus ridership, total local transit usage, and total trip making by the panelists in this survey for work/school trips, nonwork/school trips, peak-period trips, and off-peak-period trips. As indicated by this table, Mt. Pleasant bus ridership is service inelastic (ranging from about −0.3 to −0.5 in value). The elasticity of total transit usage in the area with respect to service on the Mt. Pleasant bus is, as expected, even smaller (averaging about −0.1), although the nonwork/school total transit trip elasticity is identical to the Mt. Pleasant bus elasticity. The route headway elasticities of −0.29 to −0.47 compare favorably with other results cited in the literature (*1*). There is, however, virtually nothing in the literature that corresponds to the "total transit" or service area elasticity that also has been calculated here.

SUMMARY AND CONCLUSIONS

The results of the study demonstrate the feasibility of panel surveys for identifying the response of a small sample of riders to specific headway changes on one route. This method allows researchers to control for nonservice factors and to study the behavior of different groups of travelers (e.g., transit captives, workers, etc.). These pilot test results clearly indicate that it is possible to maintain a high percentage of panelists in a survey that involves recording trip-making behavior for 4 full weeks over a 2-month period. This result, of course, depends on the simple diary format adopted, the use of a fairly attractive incentive program, and active contact between the survey team and the panel members.

Route headway elasticities comparable to those reported elsewhere in the literature were found for the test route examined. The panel survey approach, however, also allows a "total transit" elasticity, which indicates the net change of ridership for the service area, to be computed. This net elasticity is generally much smaller in value than the route-level elasticity, at least for the case examined, which involved increasing headways in an area in which alternative transit routes were generally available for travelers' use. Generalization of the results obtained here obviously will require further surveys to identify ridership responses to different types of service changes in a variety of operating environments.

ACKNOWLEDGMENTS

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REFERENCES

1. P. Mayworm, A. M. Lago, and J. M. McEnroe. *Patronage Impacts of Changes in Transit Fares and Services*, Report RR 135-1. UMTA, U.S. Department of Transportation, 1980.
2. P. R. Stopher, L. K. Tamny, K. L. Killough, and R. J. Schulte. *Mode-Choice Models, Networks, and Path Building*. Presented at the 65th Annual Meeting of the Transportation Research Board, Washington, D.C., 1986.
3. S. Algers and S. Widlert. Applicability and Stability of Logit Models in Sweden—Some Recent Findings with Policy Implications. In *Behavioural Research for Transport Policy*, VNU Science Press, The Hague, The Netherlands, 1986, pp. 173–192.
4. R. Menhard, G. Ruprecht, and I. Burns. *Route-Level Demand Models: A Review*. Report DOT-I-82-6. UMTA, U.S. Department of Transportation, 1982.
5. Roads and Transportation Association of Canada. Demand Models. In *Canadian Transit Handbook*, 2nd ed. Canadian Urban Transit Administration, Ottawa, Ontario, Canada, 1985, Chapter 6.
6. E. J. Miller. *Service Elasticity of Demand: A Study Design*. Final report to the Service Planning Department, Toronto Transit Commission. University of Toronto–York University Joint Program in Transportation, Toronto, Ontario, Canada, 1986.

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UMTA and Major Investments: Evaluation Process and Results

Samuel L. Zimmerman

The recent debates over the federal transit budget have obscured the intent and nature of UMTA's major investment rating approach. The rating approach is the logical conclusion of a project development process that has evolved over the last 15 years, was enunciated in UMTA's May 1984 notice of major investment policy (*1*), and responds to the mandate of Section 303 of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (STURAA). The development process is, therefore, well known and is only briefly discussed. The rating system, on the other hand, is covered in some detail. A number of case studies are presented to illustrate how the investment rating system developed by UMTA has worked. These case studies are divided into two groups: those projects that were highly rated as potential federal transit investments and those that did not fare well. There are features common to each type of project that tend to be the cause of their respective good or bad ratings, and these are highlighted in the paper's conclusion. One common feature of the highly rated projects is that they are generally a critical piece of a much larger system, meaning that a relatively modest investment can be leveraged to produce tremendous benefits. Another feature is that nowhere near the same level of benefits could be produced by a more modest investment. A final positive feature of the highly rated projects is that they are backed by a strong local financial commitment to transit, not only in terms of the proposed project's initial capital costs, but also in terms of long-term operations and maintenance for the transit system as a whole. The common features of the poorly rated projects are their inability to generate significant new transit ridership despite large incremental investments and the precarious financial condition of transit in the respective communities.

In recent years, the debate over the nature and level of the federal transit budget has obscured the issue of precisely what type of transit projects the federal government should support with discretionary funding and how they should be selected. Given the current federal budget situation, the Administration's transit budget proposals for the last several years have sought to terminate the discretionary capital grant (Section 3) program and have all UMTA assistance delivered through a flexible, totally formula-allocated block grant program. This calls into question the need for a major investment rating system whose main purpose is to assist in making federal discretionary decisions. The Congress, however, has chosen to continue the discretionary program.

It is, therefore, useful to talk about the UMTA project rating system for several reasons. First, it is part of a rational approach to decision making that is useful for any level of government that must operate in a resource constrained environment. Second, the Surface Transportation and Uniform Relocation Assistance Act of 1987 (STURAA) has essentially mandated the UMTA project development process. That is, it requires alternatives analysis and preliminary engineering as prerequisites for Section 3 "New Start" grants.

It also requires the Secretary of Transportation to determine that proposed New Start projects are cost-effective and supported by an adequate degree of local financial commitment, and it requires the annual submittal to the Congress of a proposed allocation of New Start funds among competing applicants. The rating system was developed to assist in making precisely these kinds of findings and recommendations.

Accordingly, this paper articulates the basic goals and objectives of the federal transit program and describes how these can be used to rate projects in terms of their federal investment worthiness. Both highly rated and poorly rated projects are described to illustrate how different types of projects fare under the rating system. The common features of both poorly and highly rated projects are summarized to show what kind of projects are most consistent with the federal interest in public transportation.

As an illustration of the discretionary decision-making environment that spawned the UMTA rating system, the aggregate cost to implement all the new fixed-guideway transit projects currently in some stage of project planning and development is over $40 billion. Arrayed against this "demand" is federal New Start discretionary funding of about $420 million per year.

In 1984 UMTA developed a major investment rating system designed to identify those proposals for capital assistance that would generate the largest amount of benefits in terms of the goals and objectives of the federal transit program. Focusing federal investments on these projects maximizes the payoff obtainable from an essentially fixed (or declining) resource.

The goals and objectives used by the rating system derive from the federal transit program's broad purpose, which is to assist the states and localities in providing a basic level of public mobility. Because of its responsibility to prudently manage public funds, UMTA cannot make investment decisions based on an interest in projects that provide maximum comfort, amenities, civic pride, and other such benefits. Therefore, these benefits are not reflected in UMTA's project-rating approach, but nothing precludes local authorities from proposing projects that do maximize them at the risk of decreasing their proposals' cost-effectiveness.

UMTA's notice of major investment policy, published in

Urban Mass Transportation Administration, U.S. Department of Transportation, UGM-20, Washington, D.C. 20590.

TABLE 1 PROJECT SUMMARY

					LOCAL FISCAL EFFORT		
PROJECT	STATUS	TOTAL COST	UMTA SHARE	UMTA COST-EFFECTIVENESS INDEX	NON FEDERAL SHARE	CAPITAL FINANCING PLAN	STABILITY AND RELIABILITY OF OPERATING ASSISTANCE
SEATTLE BUS TUNNEL	UC	$394M	$197M	$1.44/TRIP	50%	ACCEPTABLE	ACCEPTABLE
HOUSTON TRANSITWAYS	UC	$356M	$210M	$3.78 - $4.94/TRIP	40%	ACCEPTABLE	ACCEPTABLE
L.A. METRORAIL	UC/PE	$1.25B	$696M	$3.30/TRIP (1)	44%	ACCEPTABLE	ACCEPTABLE
ST. LOUIS LIGHT RAIL	FE	$384M	$289M	$9.50/TRIP	25%	(2)	DEFICIENT
MIAMI DPM EXTENSIONS	FE	$248M	$186M	$15.20/TRIP	25%	ACCEPTABLE	DEFICIENT

NOTES

(1) COST-EFFECTIVENESS INDEX IS FOR THE 8 MILE SEGMENT DEFINED IN 1983 FEIS

(2) LOCAL MATCH CONSISTED ENTIRELY OF EXISTING BRIDGE, TUNNEL AND RAIL ROW; NO CASH MATCH

(3) UC - UNDER CONSTRUCTION
FE - FINAL ENGINEERING
PE - PRELIMINARY ENGINEERING

May of 1984, institutionalized the manner in which UMTA evaluates projects competing for federal capital funding. The evaluation process it articulated uses two primary evaluation criteria, cost-effectiveness and local financial effort, to place project proposals into one of essentially three groups, those that would be highly desirable federal investments, those that would be undesirable, and those in between.

The key factors explicitly accounted for in the cost-effectiveness assessment process, consistent with the above discussion of federal goals and objectives, are new transit ridership potential; travel time-savings for existing riders; and incremental capital, operating, and maintenance costs, all compared to a base condition. These factors are combined into a "cost-effectiveness index"—in effect, the total marginal cost of attracting a new trip to public transportation.

This index is essentially computed as the total incremental cost of the given investment over the base condition, decreased by the value of travel time-savings for existing transit users, divided by the number of additional trips attracted to transit. The base condition for comparative purposes, called the transportation systems management [TSM] alternative, is comprised of modest investments in the existing transportation system designed to maximize its efficiency and effectiveness.

Though UMTA defines cost-effectiveness only in transportation terms, the factors directly accounted for are excellent surrogates for other transit-related benefits, such as reduced fuel consumption, enhanced air quality, and land development effects. Clearly, projects that attract little additional transit ridership over what would be there anyway and that do not provide travel time-savings for large numbers of existing transit riders will do little to save energy, reduce air pollution, and influence urban development.

UMTA's evaluations also reflect the nature and level of nonfederal public and private funding proposed to support construction of a given project and subsequent operation of the entire transit system of which it will be a part. Important criteria here are the share of total implementation costs that would come from nonfederal sources and the stability and reliability of local sources of operating assistance.

Other factors such as the historical involvement of the private sector (e.g., small and minority business) in the provision of public mobility, the degree of local commitment to the project, and so on, are used as additional rating criteria. These factors can help distinguish between projects that are similarly rated in terms of the two major criteria, and they can make a marginal project acceptable.

A number of projects are discussed in the next sections to illustrate how the UMTA cost-effectiveness assessment process differentiates among projects competing for limited federal funds. The projects are divided into two groups: those that were highly rated in terms of federal investment worthiness and those that were not found to be desirable federal investments because of poor cost-effectiveness and an unsatisfactory financing proposal. Both types are described in terms of their physical and operational characteristics, their potential cost-effectiveness, and the strength of the financial plan proposed to support their construction and subsequent operation (see Table 1).

HIGHLY RATED PROJECTS

Seattle Downtown Bus Tunnel

Seattle METRO is currently constructing a $435 million downtown bus tunnel that will be the critical link in a regional bus/high occupancy vehicle (HOV) rapid transit system. This system, once complete, will include about 100 mi of exclusive transit (and other HOV) lanes, over 15,000 dedicated parking spaces, and 46 transit centers or major fringe parking facilities. The key to the Seattle tunnel project's high UMTA investment rating is the factor that the clear majority of the regional bus system's over 200,000 daily riders will benefit.

The significant increases in speed and reliability afforded by off-street operation in the congested, geographically constrained regional core will not only benefit existing central business district (CBD) bound transit users, but will attract new riders and save operating and maintenance costs as well. The net result of the great new ridership and time savings potential is that the UMTA total cost-effectiveness index is only $1.44 per trip for the project.

The other feature of the tunnel project that is attractive to UMTA is that Seattle METRO is committed to paying half the aggregate cost of constructing the project (as opposed to a statutory 25 percent) and has a solid dedicated transit tax base for supporting subsequent operations and maintenance.

Houston Transitways

Houston METRO is in the process of planning or constructing transitways in the medians of five existing highways. UMTA has been asked to fund and is funding significant shares of the North, Northwest and Southwest facilities, which are integral parts of a 76-mi regional system, of which 37 mi are open. Construction is proceeding on these facilities (respectively, 19.7, 13.5, and 13.8 mi in length), and they rated well as UMTA investments because of their modest cost (respectively, $141 million, $117 million, and $98 million), their potential to attract large numbers of new riders to transit and HOVs, and the travel time and reliability improvements they would afford large numbers of existing transit users.

Neither of these benefits could be achieved without an investment in new, transit-only lanes because of intense congestion on the existing freeway system, as $3.78 to $4.94 per trip cost-effectiveness indices for the projects would indicate. In each case, the dedicated transit freeway lanes complement other investments in both on-line and off-line transit stations and fringe parking facilities. For example, the North Transitway will serve users of four existing major park-ride lots with an aggregate of 6,400 spaces, whereas the Southwest Transitway will leverage the investment already made in four park-ride lots with 3,350 spaces.

The high UMTA investment rating for the Houston Transitway projects also reflects the financial strength afforded by a 1-cent sales tax dedicated to transit. The federal share of the construction of these particular dedicated transit facilities ranges from about 60 to 75 percent with the federal transit share of the entire transitway program only 40 percent. In addition to funds from the Metropolitan Transit Authority and UMTA, both federal and state highway funding is being used to construct the transitway system.

Los Angeles Metrorail

The first 4½ mi of an eventual 18-mi heavy rail line is currently under construction in Los Angeles' Wilshire Corridor. Despite repeated alignment changes for the portion of the line beyond the initial segment because of environmental problems, the full 18-mi, approximately $3.5-billion project continues to be highly rated.

The high cost-effectiveness rating (a cost-effectiveness index of $3.30 per trip for the 8-mi segment covered in the 1983 Environmental Impact Statement) stems from a number of factors. First, even without the presence of a grade-separated transit facility, the corridor already has a tremendous number of people using public transportation. Current ridership on the Wilshire bus line, one of the busiest in the nation, exceeds 65,000 per day, and current bus ridership on all lines serving the corridor as a whole exceeds 150,000. Both are on a par with the volumes for corridors in other smaller cities which have rail lines already serving them.

This high ridership results from Los Angeles' large CBD (over 200,000 jobs, the nation's seventh largest), the large number of transit dependents in the region, the relatively dense residential development in the corridor, and congestion on the corridor's arterial street system. At the same time, the lack of close-by parallel freeways or other available rights-of-way and the near saturation of the arterial streets in the corridor make it extremely difficult to achieve improvements in transit levels of service at low cost.

The Los Angeles project also rates well from a financial perspective. Only about 56 percent of the cost of the first 4½ mi are being paid by the federal government, and there is the expectation that the federal share of the remainder of the line's construction will be similar. In addition to a variety of state taxes dedicated to transit construction, Los Angeles County has a one-half percent sales tax dedicated to public transportation capital costs and operating subsidies. Though there have been implementation problems, there are also special benefits assessment districts around all Metrorail stations with an annual tax yield of over 20 cents per sq ft of floor space.

POORLY RATED PROJECTS

St. Louis Light Rail Project

An alternatives analysis, completed in 1984 and documented in a Draft Environmental Impact Statement (DEIS), showed that simply upgrading and expanding the existing bus system at a cost of $40 million would attract more new riders than an approximately 20-mi light rail transit (LRT) line, then estimated to cost $251 million. The good showing for the much-lower-cost bus alternative reflected the high speed afforded express bus operations on the corridor's extensive and relatively uncongested arterial and freeway system.

More recent numbers from preliminary engineering suggest that under a more optimistic set of assumptions, the St. Louis LRT project could actually attract a small number of additional transit riders compared to a TSM alternative. However, this benefit would come at such a high cost that the key UMTA cost-effectiveness indicator, the marginal cost of attracting an additional rider to public transportation, would be over $9.50 per trip, far in excess of UMTA's cost-effectiveness threshold of $6.00 per trip.

UMTA was also concerned about the ability of the local area to pay for any cost overruns and to operate the resultant transit system without service reductions once the rail line is operational. St. Louis is donating abandoned railroad rights-of-way, including a bridge and tunnel, as its entire local match for the project. No cash contribution has been committed. In fact, in the early 1980s the St. Louis bus system was cut from over 800 to 625 coaches because of financial difficulties, with a resultant drop in ridership from 76 million unlinked trips in 1980 to 48 million in 1987.

Taken together, these points suggested that the St. Louis region might not possess the financial resources to both successfully implement a major transit project and operate the resultant bus and rail system in a way that would generate even the small marginal benefits the project promises.

In the Fall of 1988, per congressional direction, UMTA signed a full funding contract with St. Louis officials committing the federal government to provide $289 million for construction of the Airport LRT line. Through FY1989, the Congress had specifically earmarked approximately $150 million for the project out of UMTA's annual appropriations.

Miami Metromover Extensions

Dade County sought federal funding for two extensions to the existing Metromover downtown automated guideway loop, a 1.4-mi leg south and a 1.1-mi leg to the north, costing $240 million in total. These extensions rated poorly because of their significant cost and because they would make only a miniscule net improvement to the region's transit system.

The alternatives analysis showed that these legs would add only 2,000 riders per day to the existing Metrorail elevated heavy rail and Metromover systems' patronage. Virtually all of the new transit trips that would be generated by the project would be short trips, which could be served by other modes at far less cost. At the same time, bus ridership to and from the expanded CBD would be expected to decline by 400 trips per day because of forced transfers at the Omni station for trips destined to the city's CBD only 1 mi away. The UMTA cost-effectiveness index for the extensions, taken together, is over $15 per trip.

The last factor that contributed to the Miami projects' poor investment rating was Miami transit's precarious financial condition. Previous Miami investments in Metrorail and Metromover facilities, instead of reducing overall transit operating costs, increased the deficit to such a degree that cutbacks in bus service were required, with attendant losses of transit ridership. Miami now operates 400 buses in the peak hour, although the original plans called for a fleet of 1,000 buses to provide feeder service to Metrorail.

Through FY1989, a total of $152 million had been earmarked by the Congress for the Miami Metromover projects. The Congress had also directed UMTA to enter negotiations with Dade County leading to a federal commitment to the projects' construction. At one point, however, there was some question as to whether Dade County would proceed with the projects.

A number of individuals on the county board questioned the wisdom of building new transit facilities when there was not enough money to maintain and satisfactorily operate the existing bus, rail, and people-mover systems. It was felt that a new dedicated source of funding for transit was needed as a prerequisite for going forward. Nonetheless, at the end of March the board voted to endorse a full funding grant agreement with UMTA and proceed with the projects' construction.

CONCLUSIONS

The preceding discussion was an attempt to clarify the federal government's approach to evaluating proposals for discretionary investments in major new transit guideway facilities. This clarification is needed because the budget debates over the past several years have obscured the rigorous objective process UMTA has developed to identify those projects whose construction would generate the largest total benefit from a limited federal resource.

That process flows from the federal purpose defined in the Urban Mass Transportation Act itself (*2*). The achievement of this purpose, to assist states and localities in providing a basic level of urban mobility, is reflected in a series of UMTA cost-effectiveness indicators that directly reflect the basic transportation interest of the federal program and indirectly reflect its social, environmental, and economic objectives.

There are at least three common features of the proposals that rate highly under the system. First, the projects would be a critical piece of a much larger transit system. This results in a synergism through which a relatively modest investment can produce tremendous benefits. Second, congestion, the lack of available street space for exclusive transit use, and other factors make it impossible to achieve anywhere near the level of benefits obtainable with the proposed investments through modest improvements to the existing transportation system. Finally, the highly rated proposals generally come from communities with a strong financial commitment both to the specific project in question and to transit in general.

The first contrasting common feature of the poorly rated projects is their inability to produce significant incremental transportation (and therefore other) benefits over more modest investments in the existing transportation system, despite the great additional capital and operating cost. From a financial perspective, the poorer proposals are not backed by a strong local commitment, and the general financial state of transit in the given communities is precarious even without the additional costs associated with the proposed projects.

In closing, it should be noted that the UMTA project evaluation process results in a project being "rated" for federal investment worthiness in terms of a small number of investment worthiness indicators but does not result in a precise ranking of projects. The intention is to divide the proposals for federal funding into, essentially, three groups, those that would be most desirable as federal investments, those that would not be desirable, and those in between.

A precise ranking of projects is avoided for two basic reasons. First, the cost estimation and travel simulation processes are not sufficiently accurate to distinguish among similar projects in a way that would allow them to be precisely ordered. The second reason has to do with the way that decisions are made for discretionary projects.

UMTA recognizes that decision making on discretionary projects is a cooperative exercise involving not only the executive branch of government, but the Congress as well. In fact, STURAA effectively mandates the UMTA project development process and calls for the Secretary of Transportation to make determinations and recommendations well served by the rating system.

In Section 303, STURAA calls for the Secretary of Transportation to determine that proposed projects ultimately receiving Section 3 discretionary funding are: (a) "based on the results of an alternatives analysis and preliminary engineering," (b) "cost-effective," and (c) "supported by an acceptable degree of local financial commitment, including evidence of stable and dependable funding sources to construct, maintain, and operate the system or extension." Section 304 of STURAA calls for the Secretary to report to the Congress by January 20th of each year how the Department proposes to allocate Section 3 discretionary New Start funds among competing proposals in the succeeding year.

A precise ranking of competing projects would imply that all the positive and all the negative aspects of projects could be accounted for in a single calculus. For such a ranking process to work, trade-offs between various program goals and objectives would have to be done as part of a technical process, not by the people actually making the decisions. By simply dividing the universe of proposals into a few groups of similar investment worthiness and providing attendant technical information useful to decision makers, UMTA has more closely conformed to the intent of the Congress and best satisfied the needs of the executive branch.

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REFERENCES

1. UMTA, U.S. Department of Transportation. Urban Mass Transportation Administration Major Investment Policy: Notice. *Federal Register*, May 18, 1984.
2. *Urban Mass Transportation Act of 1964, as Amended Through February 1988, and Related Laws*. UMTA, U.S. Department of Transportation, Washington, D.C., 1988.

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Using Early Performance to Project Transit Route Ridership: Comparison of Methods

JAMES F. FOERSTER AND NEILA IMLAY

The performance of eight models for predicting ridership levels on new transit routes by using early performance data is summarized. Seven of the models are based on least-squares estimates of linear and nonlinear functions; the eighth model is a manual method based on quarterly ridership statistics. Comparisons are based on *r*-square statistics, leverage estimates, and ability to predict ridership levels for the second year of operation. The results of these comparisons indicate that (a) forecasts based on less than 6 months of data are unreliable for all conventional statistical models, (b) a simple manual method based on prior experience with other local routes is more effective than least-squares models if ridership forecasts must be produced on the basis of limited amounts of data, and (c) probit-, logit-, and power-function and linear-log models perform acceptably if more than 6 months of data are used.

Previously published reports have presented different approaches for predicting ultimate ridership levels on newly introduced bus routes. In particular, Cherwony and Polin demonstrated that a logit curve can be fit to early ridership figures to predict performance in later periods (*1*). Subsequently, Foerster et al. presented a manual method based on experience with other transit routes for this same purpose (*2*). These approaches differ from methods for predicting ridership for new routes on an a priori basis because they are based on actual route performance data (*3*).

This research was conducted to compare the performance of the previously described methods and to investigate the performance of alternative model forms. Results for all methods are presented and compared. Seven of the models are based on least-squares estimates of linear and nonlinear functions; the eighth model is a manual method based on quarterly ridership statistics. Comparisons are based on *r*-square statistics, leverage estimates, and ability to predict ridership levels for the second year of route operation.

The results of these comparisons indicate that (a) forecasts based on less than 6 months of data are unreliable for most of the models, (b) a simple manual method based on prior experience with other local routes is more effective than least-squares models if estimates must be produced on the basis of one or two quarters of ridership data, and (c) logit-, probit-, and power-function, and linear-log models perform acceptably if more than 6 months of data are available.

MODEL SPECIFICATION

Seven models were calibrated using standard statistical techniques. All used time (t) as an independent variable to predict ridership (y). Five of the functions have upper limits. The first two of these functions are the logit function:

$$y = B0/(1 + \exp[B1 + B2 * t]), \tag{1}$$

which is of particular interest because it was found to produce acceptable results in previous research (*1*), and the probit function:

$$y = B0/\Phi[B1 + B2 * t]. \tag{2}$$

The probit function is similar to the logit function, but it is somewhat easier to estimate using numerical methods. It is slightly less sensitive than Function 1 to the values of initial and final observations. This function is also of considerable interest because it represents an accepted model of the rate at which new products and services are adopted (*4*).

Three other functional forms were included in the research design because they are typically used to model asymptotic growth processes. These are the negative exponential:

$$y = B0 * (1 - \exp[-B1 * t]), \tag{3}$$

a linear model with a reciprocal transformation of t:

$$y = B0 + B1/t, \tag{4}$$

and an exponential model with a reciprocal transformation of t:

$$y = \exp[B0 - B1 * 1/t]. \tag{5}$$

Two other functional forms were included in the evaluation. These were originally chosen to serve as a baseline for comparison of the asymptotic models. As will be seen, they also provide useful forecasts. These models are the power function:

$$y = B0 * t ** B1 \tag{6}$$

and a linear model with a logarithmic transformation of t:

$$y = B0 + B1 * \ln(t). \tag{7}$$

An eighth model was calibrated with data from other transit routes instead of actual ridership for the subject route. The model yields a set of indexes that are used as multipliers to factor early ridership levels up to an expected ultimate rider-

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ship estimate. This procedure is described in a previous paper by Foerster et al. (*2*).

DATA

The data used for model calibration were provided by Pace, the Suburban Transit Division of the Chicago Regional Transportation Authority. The data consisted of weekday ridership counts for the first 361 days of operation of Route 354. Service on this route was initiated in 1987. The data were divided into two sets. The first 262 observations were used for model calibration. An additional 99 records from the second year of operation were used as a hold-out sample to test the accuracy of model forecasts.

PROCEDURES

Models 1 through 7 were calibrated using the nonlinear modeling (NLIN) procedure of the Statistical Analysis System (*5*). A variety of starting values and search techniques were used to ensure that the solutions obtained were not local minimums. Twelve calibration runs were made for each of Equations 1 through 7. Each calibration run was based on 22 * n data points for $n = [1,2, \ldots ,12]$. Ridership forecasts, r-square statistics, parameter estimates, and leverage function values were obtained for each calibration run. This, in effect, simulates the results that an analyst would obtain if ridership data were analyzed with each of the methods at the end of each month of operation.

The manual estimation technique described by Foerster et al. (*2*) was used to obtain ultimate ridership estimates. The ratios of index values for the 5th and 6th quarters to ultimate ridership index values were used to produce ridership estimates for the forecast period.

COMPARISON OF CALIBRATION RESULTS

The r-square measures of fit obtained for each of the 12 calibration runs of each model are shown in Figure 1. These values show that none of statistically calibrated Models 1 through 7 fit the observed data very well for the first 6 months of data. For the following 6 months, the logit-, probit-, and power-function and linear-log models appear to fit better than the other models. It is clear that the negative exponential, linear-reciprocal, and reciprocal-exponential models do not fit the observed data well for any calibration period.

The influence statistic $S(\mathbf{h})$ was computed for all of the calibration runs. This statistic is the standard deviation of the leverage function

$$h(i) = \mathbf{x}(i)(X'X)\,\mathbf{x}'(i) \tag{8}$$

where $X = dF/d\mathbf{B}$ and $\mathbf{x}(i) = \text{row}(i)$ of $\mathbf{X}$. Since $h(i)$ is a measure of the influence of data point i on the parameter vector $\mathbf{B}$, $S(\mathbf{h})$ is a measure of the variation of the influence each data point has on the parameters that are estimated. In general, models that have a lower value of $S(\mathbf{h})$ should be preferred because such models do not give excessive weight to any one data point. Large variances in influence values were noted for all model calibrations based on data from Months 1 through 6. In addition, it was found that the parameters of the linear-reciprocal model were more strongly influenced by a small number of data points than were those of the other models.

FORECASTING RESULTS

The forecasting ability of the models was analyzed by examining forecasted and observed ridership levels. Months 13 through 17 of route operation were used as the forecast period, and data from these months were used to test forecast accuracy. (The data for these months were not used in model calibration.)

Figure 2 shows the root mean square (rms) error that would occur if this forecast was used in an applied setting. The values indicate that the manual method produced more accurate forecasts on the basis of first- and second-quarter perfomance than any of Models 1 through 7. It can be seen that the log-linear and power-function models outperform the previously recommended logit function and the associated probit function if limited amounts of data are available. Furthermore, it

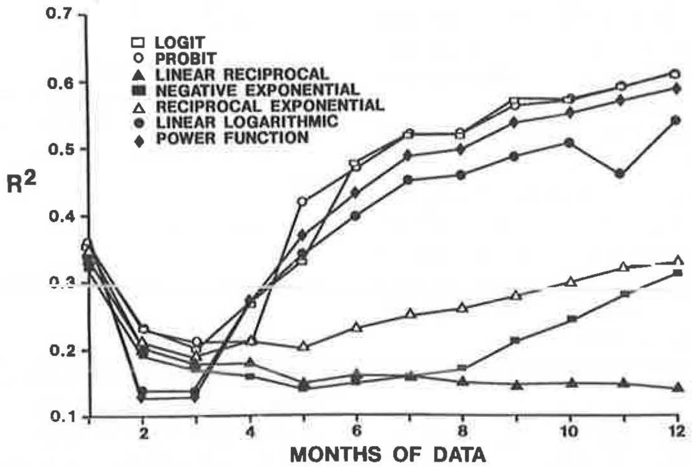

FIGURE 1 Model fit statistics.

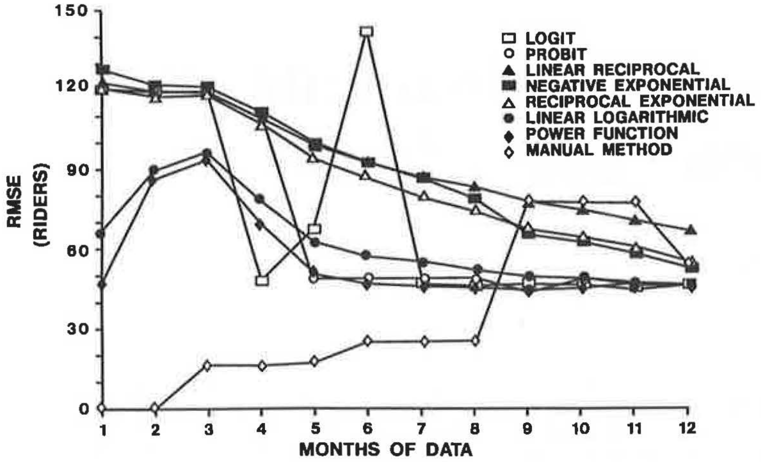

FIGURE 2 RMS forecast error.

appears that use of the manual method is preferable if forecasts must be generated during the first 6 months of route operation because of high error rates for all of the statistically calibrated models.

SUMMARY

These results are by no means conclusive. Although over 300 data points, 8 models, and 12 calibration runs per model were used, our sample has consisted of only one route. Different results may be obtained by other analysts using data from other locations.

However, we have shown that it may be misleading to develop trend forecasts for new routes, regardless of the functional forms used, if only a few months of data are available. We have also shown that simpler manual methods that take advantage of local experience should be given every consideration in spite of their simplicity. In fact, these methods may even be preferable because they can be applied in 5 to 10 min with the aid of a hand calculator, in contrast to the time and expense associated with developing calibrations for more-sophisticated, yet less-accurate statistical models.

Continuation of this research is clearly warranted. We will continue to observe the performance of the route in question and update our comparison of the forecast performance of the models considered. The results we have reported should be validated by subjecting additional data to similar analyses. We would gladly do this for any property willing to submit daily ridership data. In addition, we see a need to refine all of the methods to account for seasonality; this would be most easily accomplished by applying correction factors based on system-level trends.

REFERENCES

1. W. Cherwony and L. Polin. Forecasting Patronage on New Transit Routes. In *Traffic Quarterly*, Vol. 31, No. 2, April 1977, pp. 287–295.
2. J. F. Foerster, A. Jones, and D. Fisher. Monitoring Performance of New Bus Routes. In *Transportation Research Record 1165*, TRB, National Research Council, Washington, D.C., 1988, pp. 69–74.
3. Route-Level Demand Models: A Review. Report DOT-I-82-6. UMTA, U.S. Department of Transportation, 1982.
4. M. E. Rodgers. *Diffusion of Innovations*. Free Press, New York, 1962.
5. *SAS Users Guide: Statistics, Version 5 Edition*, SAS Institute, Inc., Cary, N.C., 1985.

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Institutional Requirements for Competition: Labor Issues

Darold T. Barnum

This paper identifies the labor requirements applicable when transportation organizations want to increase competition through subcontracting or service contracting and suggests methods for meeting those labor requirements. The paper defines subcontracting and service contracting, identifies the major sources of labor requirements and the organizational types that are affected by each source, discusses the labor requirements in detail, and suggests ways of effectively dealing with the requirements. Although the paper specifically addresses those labor requirements that must be met in order to increase competition through subcontracting and service contracting, the discussion is also relevant to other organizational modifications that change the number or identification of transit service providers.

In order to increase competition in urban mass transportation, it is necessary to deal effectively with the institutional requirements that envelop the industry (*1*). One type of institutional requirement that almost always must be addressed involves the labor issues (*2,3*). Frequently, labor requirements are seen as the major obstacle to increased competition. Indeed, they often place restraints on the type and extent of competition that can take place in the short run. Over time, however, there often are ways in which the desired competition can be introduced while meeting labor requirements.

The purpose of this paper is to identify the labor requirements involved when transportation organizations want to increase competition through subcontracting or service contracting and to suggest methods for meeting those requirements. The paper first defines subcontracting and service contracting. Next it identifies the major sources of labor requirements and the organizational types affected by each source. Then it discusses the labor requirements in detail and suggests ways of effectively dealing with them.

TYPES OF COMPETITIVE ARRANGEMENTS

Efforts to increase competition in transit have primarily included the use of two basic approaches. They are (a) subcontracting by operating agencies and (b) contracting for service by nonoperating agencies (*2*). Under subcontracting, a transit system contracts out part of its operations to other public- and private-sector organizations. The subcontracted work could involve transit service, maintenance, or any other activity. Subcontracting's central characteristic is that an operating agency contracts out activities that it does or could perform itself. The subcontracting approach is the easiest to implement and is the most common.

Service contracting, or contracting for service, is also sometimes called fully competitive bidding. Under service contracting a nonoperating agency, such as a funding or planning body, contracts with private and public transit suppliers for the provision of transit service on various routes or geographic areas within its jurisdiction. Service contracting's central characteristic is that a nonoperating agency contracts out activities that it would never perform itself because they involve various aspects of operating transit service.

Privatization of transit service often uses the same techniques as competitive arrangements, although privatization itself does not require competition and only allows private-sector firms to participate. This discussion of labor requirements, however, is equally applicable to the use of subcontracting and service contracting under both privatization and competitive initiatives.

Both the subcontracting and service contracting approaches could be used in the same geographic jurisdiction, of course. But, subcontracting would be used only by operating agencies, and contracting for service would be used only by nonoperating bodies. And, as discussed next, subcontracting requires the consideration of both collective bargaining and 13(c) requirements, whereas service contracting usually invokes only 13(c) provisions.

SOURCES OF LABOR REQUIREMENTS AND ORGANIZATIONS COVERED BY EACH

The most common labor requirements come from two main sources. One of these sources is an agency's collective bargaining agreement, as governed by state public employee collective bargaining laws, the National Labor Relations Act as amended, and other legislation. The other source is an agency's 13(c) agreements, as required by Section 13(c) of the Urban Mass Transportation Act of 1964 as amended, referred to herein as the UMT Act (*4–6*).

The requirements that a particular agency is subject to depend on the agency's institutional and financial situation. The key institutional factor is whether an agency operates a transit system or whether it is a nonoperating organization such as a funding or planning agency. Nonoperating agencies do not employ transit workers; thus they sign no collective bargaining

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agreements, and state and federal laws concerning collective bargaining are not applicable to them. Operating organizations do employ transit workers; thus state and federal collective bargaining laws are applicable to them, as are existing collective bargaining agreements for those that employ unionized workers.

The key financial factor is whether federal aid is received for the project. This is because 13(c) requirements only apply when federal assistance is directly or indirectly used by an agency.

Thus, if no federal aid is received for the projects in question, a nonoperating agency generally is not covered by either collective bargaining or 13(c) requirements, and a unionized operating agency generally is subject to only collective bargaining agreements. If federal aid is received, a nonoperating agency generally is covered only by 13(c) requirements, but a unionized operating agency generally is covered by both collective bargaining agreements and 13(c) requirements. That is, when federal aid is received, subcontracting could potentially invoke both collective bargaining and 13(c) requirements, whereas service contracting would normally involve only 13(c) requirements.

Some agencies occasionally may be faced with additional labor requirements. Although not examined in this document, these can come from local, state, and federal government sources (*7*).

COLLECTIVE BARGAINING AGREEMENTS

The labor requirements that can have the most impact on an operating agency's workers are found in the collective bargaining agreement between the agency and its employees (*8*). Collective bargaining agreements mainly restrict attempts of transit operating agencies to subcontract, with service contracting by nonoperators being inapplicable.

In the following discussion of the impact of labor agreements on subcontracting, four subjects are covered: (a) agreements with specific language on subcontracting, (b) agreements without specific language on subcontracting, (c) notification of the union of intent to subcontract and duty to bargain over it, and (d) potential for modifying agreements. The following four subsections address each of these subjects in turn and suggest ways for dealing with their requirements.

The discussion is illustrated with the outcomes of applicable transit arbitrations that have occurred since 1977. A classification of the arbitration cases is presented in Table 1. Of the 15 cases, 2 considered 13(c) agreements only, 2 concerned both 13(c) agreements and collective bargaining agreements without subcontracting language, 5 involved only collective bargaining agreements without subcontracting language, and the final 6 examined only collective bargaining agreements with applicable subcontracting language. The detailed criteria used by arbitrators when collective bargaining agreements contain no subcontracting language are presented in a later section, and the 13(c) issues are presented in the sections covering 13(c) protections. Of the 15 cases, management won 8 and the union won 6, so there has been no clear victor. Also, it is interesting to note that 6 of the 15 cases, or over one-third, have occurred in the last 2 years.

Collective Bargaining Agreements with Specific Language on Subcontracting

In some cases, the collective bargaining agreement may specifically cover the subject of subcontracting. Provisions related to subcontracting often are found in a management rights clause or a subcontracting clause. Following are three examples of language seeking to ensure certain rights for management (*9*):

- The agency has the right to subcontract any work.
- The agency has the right to subcontract any work unless it would result in the layoff, transfer, or demotion of any bargaining unit employee.
- The agency has the right to subcontract any work if the subcontracting would result in lower costs or more efficient operations.

More commonly, the agreement contains subcontracting language designed to prevent or limit subcontracting and sometimes succeeds in doing so (*10,11*). However, clear contract language is applied strictly by arbitrators, so the mere existence of language limiting subcontracting does not necessarily prevent it. An example of such language, which seems to restrict management but, in fact, permitted substantial subcontracting, is provided by a 1987 arbitration involving the Fort Wayne Public Transportation Corporation (PTC) (*12*). Management had subcontracted service that included some regular fixed-route lines that had previously been operated by its own employees. The union grieved, citing the following subcontracting clause: "The Company shall not contract out or subcontract out or hire part-time employees to perform any work normally performed by the employees within the bargaining unit which would result in lay off, transfer or demotion of these employees." Since no employees were laid off, transferred, or demoted, the arbitrator ruled that the subcontracting was permissible.

The Fort Wayne case illustrates another point as well. As is explained in the next subsection, employees and management each have well-established rights when the contract is silent on subcontracting. However, if subcontracting is specifically covered in the agreement, this language is applicable to any subcontracting activities. Thus, for management as well as for labor, the presence of subcontracting language will change their rights. However, the specific changes that occur are not necessarily obvious without careful examination (*13*).

In sum, when an agreement includes clear, specific language about subcontracting, all parties are bound by the provisions during the agreement's life. However, new provisions may be negotiated in the next agreement. Thus, if management wants to subcontract in the future, and the current agreement contains language that does not permit the type of subcontracting desired, management should plan ahead and attempt to negotiate the necessary rights into its next agreement.

Collective Bargaining Agreements Without Specific Language on Subcontracting

Most transit collective bargaining agreements do not specifically address the topic of subcontracting in any part of the

TABLE 1 CRITERIA USED IN 15 TRANSIT ARBITRATIONS INVOLVING SUBCONTRACTING, 1977–1988

CRITERIA	CASES #	CASES %
13(c) Agreement Language	4	27
Subcontracting Language in Collective Bargaining Agreement	6	40
Collective Bargaining Agreements Without Subcontracting Language:	7	47
Justification for the Subcontracting	7	47
Effect on Union, Bargaining Unit and Labor Agreement	7	47
Effect on Bargaining Unit Employees	7	47
Type of Work Involved	7	47
Past Practice	3	20
Duration of the Subcontracted Work	3	20
History of Negotiations on Subcontracting	1	7
Availability of Properly Qualified Employees	1	7
Availability of Equipment and Facilities	1	7
Regularity of Subcontracting	1	7
Atypical Circumstances Involved	1	7

Notes: Percentages are the number of cases in the category divided by 15. Of the 15 cases in total: 2 involved only 13(c) agreements; 2 involved both 13(c) agreements, and collective bargaining agreements without subcontracting language; 5 involved only collective bargaining agreements without subcontracting language; and 6 involved only collective bargaining agreements with subcontracting language.

contract. The fact that the agreement is silent, however, does not give management the unilateral right to subcontract whatever and whenever it chooses. That is, the very fact that there is an agreement establishes certain employee rights concerning subcontracting. On the other hand, management does retain significant rights to subcontract under a silent agreement (*14*).

Arbitrators have developed a number of standards that identify the circumstances under which subcontracting can occur when the labor agreement is silent on the subject (*14*). The most common of these, with examples from recent transit arbitrations, are covered next. The first four standards are key. They have been present in all of the arbitration cases involving transit subcontracting under collective bargaining agreements silent on the subject, and they are likely to be present in most future cases. Each of the remaining seven standards has been a factor in one or more recent transit subcontracting cases. Although these standards are less likely than the first four to be relevant to a particular case, it is certain that they will be used when applicable.

1. *Justification for the subcontracting*. It is always necessary to have well-documented reasons for subcontracting, such as lower costs, efficiency, or other sound business reasons.

In one case, for example, the arbitrator asked (*15*), "Had the employer made a reasonable 'efficiency and cost' decision when it was determined by COTA [Central Ohio Transit Authority] to subcontract this special project? This is, clearly, a most important question." After looking at the evidence, the arbitrator determined that management had done so, even though the union made a "very lengthy presentation" trying to show that the cost differences were slight.

Likewise, after noting that the decision must be justified and examining the evidence, a variety of arbitrators ruled as follows. The Transit Authority of River City (TARC) (*16*) had made a reasonable efficiency and cost decision; TARC (*17*) had acted in good faith because there were major savings and it was a practical impossibility for the company to schedule the work efficiently; the Chattanooga Area Regional Transportation Authority (CARTA) (*18*) had established legitimate reasons for subcontracting in the record; the Chicago Transit Authority (CTA) (*19*) subcontracting could be justified on the basis of all relevant evidence as a normal and reasonable management action, because of a consulting study and other cost analyses. In the Transit Authority of Lexington-Fayette County (LexTran) (*20*), the arbitrator noted the well-documented financial difficulties and the presence of UMTA regulations requiring privatization. Significantly, the arbitrator stated that UMTA pressure alone would not justify subcontracting.

2. *Effect on the union, bargaining unit, and labor agreement.* Subcontracting may not be used as a method of discriminating against the union. It should not hurt the status or integrity of the bargaining unit; that is, it should not have the effect of seriously weakening the bargaining unit or important parts of it. It should not result in subversion of the labor agreement.

For example, in the 1987 TARC case (*16*), the arbitrator noted that he had found no evidence that the subcontracting was motivated by antiunion animus. At COTA (*15*), the arbitrator addressed the question of whether the subcontracting undermined the bargaining unit or the security of the union as an institution. He found no evidence that this was intended by management, nor any evidence that this would be the unintended result. The size of the unit had been growing and was expected to grow even more. Significantly, the arbitrator noted that, "This . . . small project, involving approximately 10 operators and 2 mechanics, is very small compared to the work force of over 400 employees in the COTA bargaining unit."

However, in their decisions, many arbitrators noted that the effects of subcontracting on the bargaining unit had been minimal. They cautioned that the level of subcontracting could not be increased without the possibility of a change in their decisions. For example in the June 1987 LexTran case (*20*), the arbitrator noted that the integrity of the bargaining unit had not been injured by the contracting out of three fixed-route bus routes, which had only been in existence for a short time and were little used. However, he cautioned that if the authority contracted out additional routes, the bargaining unit's integrity might be seriously jeopardized, and the current decision would not prejudice a future union claim following any additional subcontracting.

In a few cases, injury to the integrity of the bargaining unit has been a key factor in arbitrator decisions preventing subcontracting. In an arbitration involving the Portland, Maine, Metro (*21*), in which management planned to use private providers to operate handicapped services, the arbitrator ruled against management. A prime reason was that the subcontracting would undermine the bargaining unit. And, in ruling against subcontracting at the South Bend, Indiana, PTC (*22*) in a case involving only one part-time maintenance employee at a remote substation, the arbitrator held that, "it was not shown to be the parties' intent to freeze the size of the bargaining unit by allowing the permanent subcontracting in of new work which could be done cheaper by outsiders."

The prevailing position, however, is that subcontracting will be allowed under this standard if the effects on the bargaining unit and the collective agreement are "small" and if there is no trace of antiunionism involved.

3. *Effect on bargaining unit employees.* An argument for allowing subcontracting is that members of the bargaining unit have not been discriminated against, displaced, deprived of jobs previously available to them, or laid off as a result of the subcontracting. Unless the agreement contains an overtime guarantee, loss of overtime earnings is not an important consideration.

The fact that no bargaining unit employees had been laid off was given as a reason for allowing subcontracting by the arbitrators in every transit arbitration examined where the contract was silent on subcontracting and the arbitrator did permit subcontracting. No transit employees have been laid off in any of the arbitration cases to date, so it is not known how much weight the presence of layoffs would receive. However, its frequency of mention indicates that it would be a major factor in any decision.

In the COTA case (*15*), as well as in some but not all of the others, the arbitrator went even further. At COTA, the arbitrator considered not only whether any employees had been laid off but also whether jobs that were traditionally performed by bargaining unit employees would be denied them.

A similar issue is that of bargaining unit positions vacated by attrition being shifted to a subcontractor, thereby decreasing the unit size without layoffs. Because this has not occurred in any arbitrated case to date, it has not been considered by transit arbitrators. However, significant declines in the size of the bargaining unit, even if accomplished by attrition rather than layoffs, would probably be a factor in the union's favor (*12*).

In sum, when an arbitrator has allowed traditional work to be subcontracted, the decision often has been conditioned upon the fact that only a small amount of work was involved and the integrity of the bargaining unit had not been injured. This leads to the fourth key criterion—the type of work involved.

4. *Type of work involved.* If the work subcontracted is of the type normally performed by bargaining unit employees, this is an argument against subcontracting. But, if the work is frequently subcontracted in the industry, or is of a marginal or incidental nature, this argues in favor of allowing it.

Arbitrators have made clear references to the centrality of the type of work in justifying their decisions. For example, in the 1982 CTA arbitration (*23*), which involved subcontracting of security work, in ruling for management the arbitrator acknowledged that security was a support function. He stated that he might have ruled for the union if the central functions of the bargaining unit, such as vehicle operation, were involved. At CARTA (*18*), the arbitrator considered whether the work was "adjunct type services, like office cleaning," and implied that "door-to-door service with small, specially equipped vans to accommodate a limited number of handicapped or semiambulatory passengers" is an adjunct type service.

Whether demand-responsive service, service using vans, service limited to certain groups, or some combination of these factors is considered to be the type of work "normally performed" by bargaining unit members will depend on the case at hand. New demand-responsive van service for special groups was found not to be dissimilar from traditional service at the MBTA (*10*). Although the MBTA argued that the dial-a-ride operation was new and uniquely different from the service that the authority had traditionally provided, and therefore was not "bargaining unit work," the arbitrator found that, "Just as the size of the vehicle is not decisive of whether it is bargaining unit work, neither fixed routes nor regular schedules control that question." But, such work has been found to be dissimilar in some cases. At COTA for example (*15*), the arbitrator found that the newly instituted demand-responsive service for special groups did differ from "the work of driving the large coaches traditionally done by members of the bargaining unit, to transport the general public." In sum, a decision as to whether demand-responsive service, service using vans, service to special groups, or any combination is significantly different from traditional fixed-route service with large coaches will depend on the particular set of circumstances involved. However, it would seem that if an agency has offered only fixed route/time service using large buses in the past and decides to subcontract demand-responsive service for special groups using vans, this work usually would be considered different.

To summarize the first four standards—arbitrators always require that the subcontracting be justified; then they often apply the remaining three standards as a set, with the net effect that all three are the relevant factor. The next seven standards are also important but have not been applicable as often as the preceding four.

5. *Past practice.* If the parties have exhibited a clear pattern of behavior concerning subcontracting in the past, that practice is evidence for what is permissible under the current agreement.

For example, when LexTran (*20*) contracted out three lightly used fixed routes, the arbitrator noted that subcontracting had been used to replace uneconomic fixed-route service in the past, albeit with demand-responsive vehicles. In the 1987 TARC case (*16*), the arbitrator noted that past practice and bargaining history tended to favor the right of subcontracting, because some contracting out had occurred since 1980, and the union had never brought it up in negotiations.

6. *Duration of the subcontracted work.* It is more likely that the subcontracting will be allowed if the work is subcontracted for a temporary or limited period and less likely it will be allowed if it is subcontracted for a permanent or indefinite period.

The fact that the work would be temporary was an important factor in several transit cases. For example, at COTA (*15*) the arbitrator noted that subcontracting of the service "may not be permanent, since COTA stressed the experimental nature of the service to be contracted for only a year." More strongly, the CARTA (*18*) arbitrator stated "Finally, and perhaps most important of all, this is only an interim service which is scheduled to lapse as soon as the larger buses equipped to handle handicapped passengers are ready for operation." And in the 1987 TARC arbitration (*16*), the arbitrator cautioned that "If this route becomes permanent . . . some of the fundamental assumptions underlying this decision would cease to be present. If this occurred, the decision herein should be reexamined."

7. *History of negotiations on subcontracting.* If either party has attempted to gain certain subcontracting rights during new contract negotiations and failed, this is considered as evidence that such rights are not part of the agreement.

An example is provided by the 1985 Chicago CTA arbitration (*19*). The arbitrator noted that "the fact that the Union proposed contract language prohibiting subcontracting suggests the Union recognized the fact that the collective bargaining agreement does not specifically prohibit subcontracting."

8. *Availability of properly qualified employees.* Are bargaining unit members with appropriate skills available to do the work? If they are, this would be an argument against allowing subcontracting; if they are not, this would be a strong argument in its favor.

For example, in the Boston MBTA case (*10*), management argued that their ordinary drivers did not have the training and skills needed for their demand-responsive handicapped service. In this case, the arbitrator rejected the argument, saying that drivers hired for the demand-responsive service had often obtained the training and skills after being hired.

9. *Availability of equipment and facilities.* An argument for allowing subcontracting is that necessary equipment and facilities are not available and cannot be economically purchased.

For example, in the 1980 TARC arbitration (*17*), the arbitrator noted that, "The evidence showed that the cleaning is more sophisticated than that performed by the Company's janitorial staff and requires equipment that the Company does not have."

10. *Regularity of subcontracting.* Arguments favoring subcontracting would be that this was the first time the job had been necessary or the work is so intermittent and irregular as to make it infeasible to hire permanent employees to perform it.

The 1980 TARC arbitration (*17*) provides an example of the use of this criterion. In ruling that the subcontracting was permissible, the arbitrator said that:

> In the case at hand, we are dealing with an unusual situation in that janitorial service is required on a short time basis in the early hours of the morning . . . . The working hours vary from 2 to 5 hours and the complement (of workers needed) fluctuates from two to four or more depending on the type of cleaning required . . . . The fluctuating nature of the work performed by the subcontractor makes it a practical impossibility for the Company to schedule the work efficiently.

The eleventh and final standard, involving unusual situations, is discussed next.

11. *Atypical circumstances involved.* Subcontracting may be justified when it is necessitated by an emergency, some urgent need, a deadline, or other circumstances not usually present.

For example, in 1986, because of a large number of car door openings on trains in motion, the New York City Transit Authority (NYCTA) (*24*) farmed out the work of examining and repairing the doors. There were several arbitration decisions over a period of time on the matter, and there was some applicable contract language. However, the following statement by the arbitrator well illustrates the criterion being examined:

> I have viewed this situation from the inception of the arbitration as a severely troubling, if not an emergency, matter. In fact, had it not been for my concern for the safety of the public, I likely would have found that the contract required the immediate and complete removal of the Vapor (subcontractor) employees from the 207th Street shop.

To summarize the discussion of all eleven standards—in the absence of collective bargaining agreement language specifically dealing with subcontracting, the particular situation at hand should be considered in determining if subcontracting will be allowed. If the weight of the evidence from the criteria will convince an arbitrator that the subcontracting is reasonable and undertaken in good faith, then it will be allowed. As should be clear from the transit cases cited, arbitrators often have ruled for management. So, if reasonableness and good faith truly are present, it usually is possible to convince an arbitrator that this is so.

Although arbitral decisions become part of the existing collective agreement between the parties for the duration of the contract, they are open to renegotiation and change in future contracts. That is, if an agreement is silent on subcontracting and management has lost or feels it would lose before an arbitrator, it still can obtain its end by negotiating appropriate language when bargaining the next contract with the union.

Notice of Intent and Duty to Bargain Collectively

The previous sections have examined the labor requirements concerned with what work may be subcontracted during the term of the collective bargaining agreement. This section examines labor requirements concerned with the *process* of making subcontracting decisions. There are two main process requirements to be considered. The requirements are, first, the notification of the union of intent to subcontract and, second, the duty to bargain with the union about subcontracting.

If management plans to engage in subcontracting of a different type or to a significantly greater degree than it has done in the past, it must carefully follow any notification or bargaining requirements specifically included in its current agreement. Even if the agreement says nothing about notification, management usually is required to notify the union about an intent to subcontract, whether the intent develops during new contract negotiations or during the term of an agreement (*25,26*).

Likewise, during new contract negotiations, or under a silent agreement during its term, usually management is required to bargain with the union over subcontracting if the union specifically asks to do so. However, good faith bargaining does not require management to alter its initial position, unless the union has truly convinced it that it should do so. At the end of such bargaining, if the parties have reached an impasse, then management has the right to implement its final position. Note, however, that under some public employee collective bargaining laws, it may be necessary to use certain impasse resolution procedures such as mediation or fact finding before implementing the subcontracting (*25,26*).

If an impasse is reached under an agreement silent on subcontracting, and management implements its final position, the union has the options of doing nothing, filing a grievance, which could lead to arbitration, or going to a state public employee relations board or court. If the union does nothing, obviously management will be able to continue the subcontracting. If the union files a grievance and pursues it to arbitration, the arbitrator will rule based on the standards applicable to a silent contract. If the union takes the case to a board or court, which is likely to occur only if the state has a comprehensive collective bargaining law, that body will determine whether management bargained in good faith with the union on the topic. If the board or court determines that management did bargain in good faith, even if management did not change its initial position, it will support management's implementation of its final offer.

Regardless of the scenario, during either new contract negotiations or during the term of an existing agreement, management should not forgo its option to act for fear of union reaction. However, management should obey all applicable agreement provisions. If the agreement is silent on subcontracting, management should notify the union of its intent to subcontract well in advance of signing a subcontracting contract and, if the union specifically requests to do so, should bargain in good faith about the subcontracting with the union, following procedures mandated in applicable collective bargaining laws. If agreement cannot be reached, management should proceed to subcontract as specified in its final position. In short, management should take decisive, but not impetuous, action to attain its ends.

New Collective Bargaining Agreement Negotiations

The final factor that can affect subcontracting decisions is the potential for modifying the agreement during new agreement negotiations. If management feels that it cannot subcontract in the way that it wants under its current agreement, it can attempt to obtain the needed language in its next labor agreement. Restrictions imposed by a silent agreement, specific agreement language, arbitration decisions, and binding past practices can be removed if appropriate language is inserted in the next agreement.

Changes in agreement language are not normally possible except when the contract is being renegotiated. Thus, if decision makers are considering the possibility of subcontracting in the future, they should remember this when planning for contract negotiations. In short, if the current agreement does not provide sufficient rights, then it is important to plan ahead and negotiate for them, so the necessary rights will be present to allow subcontracting thereafter.

In some cases, a union may be willing to give up substantial economic benefits in return for obtaining a favorable subcontracting clause or may require substantial economic benefits for removing one from the agreement. This may have a significant impact on the cost advantages of subcontracting. For example, the union may agree to lower wages for certain occupations or be willing to bid for certain work, thus affecting the relative cost differences between doing the work in house and contracting it out. That is, the threat of subcontracting can be used as a very potent argument for obtaining cost savings. Indeed, the concessions obtained from agreeing not to subcontract might be equal to or greater than the hoped-for savings from subcontracting.

In sum, decision makers should expect subcontracting issues to flow over into regular contract negotiations whether or not there is specific language in the current agreement. They must determine whether the benefits of obtaining, or giving up, subcontracting rights are worth the costs. They should consider the advantages and disadvantages of subcontracting in terms of the effects on (a) costs and revenues, (b) the desired labor-management relationship, and (c) other key elements of the system's strategy.

The second major source of labor requirements is Section 13(c) of the UMT Act and the resulting 13(c) agreements (*13*). The next two sections discuss the effects of 13(c) requirements on attempts to increase competition through subcontracting or service contracting and how to deal with the situations.

13(c) AGREEMENTS

Section 13(c) of the UMT Act, as interpreted by its legislative history, requires that "13(c) agreements" be signed by recipients of federal aid (*4–6*). If employees represented by unions may be directly or indirectly affected by a project, the 13(c) agreement is negotiated by the recipient and the involved unions. The 13(c) agreements detail the exact nature of the protections. Certain minimum protections are set by the law, although the law itself notes that these minimums will not necessarily be sufficient or standard. The specific conditions applicable to a given case are negotiated and agreed to by the parties directly involved, with impasses being resolved by the Secretary of Labor, whose decisions are reviewable by the federal courts.

Although 13(c) agreements are tailored to fit the circumstances of each case, most tend to be similar. For example, most of the agreements for operating aid are patterned after the National Employee Protective Agreement of 1975, often referred to as the model agreement or the national agreement (*4*). Indeed, the model agreement is frequently adopted verbatim by the parties.

There are a number of provisions in the model agreement that can affect subcontracting, including those involving advance notice requirements for operational changes (Paragraph 5), compensation due to adversely affected workers (Paragraph 6 and others), priority of employment for dismissed employees (Paragraph 18), successor provision (Paragraph 19), and, most important, the sole provider requirements (Paragraph 23). Only the sole provider requirement is discussed here.

Paragraph 23 of the model agreement contains the requirement that the federal aid recipient shall be the

> sole provider of mass transportation services to the Project and such services shall be provided exclusively by employees of the Recipient covered by this agreement, in accordance with this agreement and any applicable collective bargaining agreement.

However, subcontracting that predates the 13(c) agreement may continue. In its most restrictive interpretation, this paragraph prevents federal aid recipients from subcontracting work that has not been historically subcontracted. Most arbitrators and transit labor relations authorities who have taken public positions on the matter have stated that the language supports the restrictive view, although not everyone agrees.

However, if an operator's collective bargaining agreement does permit subcontracting while its 13(c) agreement does not, which will prevail? In three of the four arbitration awards that have been issued on the question through mid-1988, the arbitrators have said that the sole provider language in Paragraph 23 of the model agreement will be binding *only* if it does not conflict with the collective bargaining agreement (*16,18,27*). The three applicable collective bargaining agreements were silent on subcontracting, but the arbitrators held that the desired subcontracting was permitted under them. Hence, because the collective bargaining agreements permitted the subcontracting, and the collective bargaining agreements were ruled to prevail, the subcontracting was permitted.

In the fourth case (*28*), the arbitrator ruled that the 13(c) agreement's subcontracting prohibitions should prevail over a collective bargaining agreement silent on the subject and prohibited the subcontracting. This ruling directly conflicts with the other decisions.

There undoubtedly will be more arbitrations on the problem, so a definitive answer may not be available for some time, if ever. Moreover, in all cases to date, the collective bargaining agreement was silent concerning subcontracting, so the arbitrators were considering management rights under silent collective bargaining agreements versus management rights under a 13(c) agreement with specific subcontracting language. It would appear that the collective bargaining agreement would be increasingly likely to prevail if it contained specific language permitting subcontracting, if its language was negotiated after the 13(c) agreement was signed and if its language specifically provided that it would prevail over all other agreements.

In sum, in most cases to date, management rights under a collective bargaining agreement have prevailed over subcontracting restrictions in the 13(c) agreement for operating aid. But, the outcome of a particular case will partly depend on the specifics concerning the case in question and the arbitrator involved.

It is important to note that some capital, demonstration, and other 13(c) agreements have unique provisions regarding subcontracting. Often these are much less restrictive than those found in the model agreement for operating aid. For example, some 13(c) agreements provide that subcontracting can occur as long as the project service does not compete with, displace, or substitute for existing fixed-route service already provided by the employees of the recipient system. Moreover, some unions have been willing to agree to modifications allowing subcontracting in appropriate circumstances, so decision makers should consider bargaining for such provisions even if their current 13(c) agreements do not allow it.

DEALING WITH 13(c) ISSUES

In the initial planning stages for a subcontracting or service contracting project, decision makers should early determine if an existing 13(c) agreement covers the situation. A decision to begin subcontracting or contracting for service in the normal course of operations would often be covered by the current operating agreement, assuming federal operating aid is being used by the system on an ongoing basis. Situations in which current agreements usually would not be applicable would be those in which a new demonstration project is being contemplated or a new capital purchase is involved.

When an existing 13(c) agreement is applicable, decision makers should carefully read it in its entirety early in the planning stage for the competitive initiative. They should determine if their agreement restricts or prohibits their ability to take the desired actions and should carefully observe any notification and other requirements. They should understand that adversely affected workers must be compensated only for those effects caused by a federally aided project.

If the desired activities are restricted or prohibited by applicable 13(c) agreements, decision makers should consider changes in the competitive projects that would achieve their goals while meeting the labor requirements. However, it is important to remember that several arbitrators have ruled that subcontracting restrictions in 13(c) agreements based on the model agreement are not binding if they conflict with the agency's collective bargaining agreements. If 13(c) restrictions are binding, and acceptable changes in the projects cannot be made, it may be necessary to attempt to negotiate 13(c) agreement revisions or to negotiate changes in the collective bargaining agreement that would take precedent over the 13(c) restrictions. In some situations, it might be possible to fund the project with nonfederal revenues that have been appropriately segregated from federal subsidies; however, this is a complex matter and should be undertaken only with the assistance of counsel completely knowledgeable of 13(c) requirements, practices, and procedures.

If possible, projects should be designed to avoid adverse impacts on current transit workers. If there will be an adverse effect, and it is caused by federal aid, decision makers should determine the cost of compensating the involved workers. In those cases where the benefit of the project is greater than the cost, the project should proceed and the claims should be settled. That is, decision makers should not let the prospect of a union grievance or the possibility of adverse effect claims stop a project.

If applicable 13(c) agreements do not provide the needed rights or a new agreement is needed, then it is necessary to plan far ahead for the negotiations. Ideally, a new 13(c) agreement should be individually tailored to fit the situation at hand. Often it may be most practical to accept the terms commonly included in similar agreements, but each provision should be carefully examined to be sure that the desired competitive projects will be allowed under it. For example, if an agency plans to apply for a capital grant to buy buses that will be leased out to a subcontractor or the winner of a bid, it should make sure that its 13(c) capital agreement allows it.

Effective negotiations take time and effort. When a new or revised 13(c) agreement is needed for a competitive project, negotiations with the unions should be started early in the planning process. This is true, not only for new capital and demonstration agreements, but also for revised operating agreements. That is, even though an agency's operating agreement can be renegotiated every year, project timing or negotiating strategy can sometimes result in a long delay before the desired language can be reasonably obtained. In many respects, 13(c) negotiations resemble union-management bargaining over other topics, and use of similar knowledge, skills, strategy and tactics may help to attain a desirable agreement.

If agency decision makers have bargained in good faith with the unions but have reached a true impasse, they should approach the U.S. Department of Labor (DOL) and explain the situation fully. Sometimes the DOL may be able to suggest alternatives or procedures for resolving the impasse that are acceptable to the parties. If this does not work and the Secretary of Labor is convinced by the parties that they have negotiated in good faith, he or she will issue a determination concerning the issues at impasse and will advise the parties of the protective terms and conditions upon which the 13(c) certification will be based.

In a number of cases, the involved union has agreed to 13(c) language that specifically permits subcontracting. For example, subcontracting frequently has been allowed with language such as the following: "Project services shall not compete with, displace, or substitute for existing fixed-route service provided by employees of the recipient system." This particular provision may not meet the needs of some agencies, but it does illustrate that often the unions are responsive to agencies' need to subcontract. And, by use of the give-and-take common to regular agreement negotiations, mutually acceptable terms often can be worked out.

CONCLUSIONS

Transit labor protection requirements imposed by law and union-management agreements are compromises between the legitimate desires of transit providers to improve performance and the legitimate desires of workers for job security. However, the necessity of public policy to address both needs gives little comfort to those who want to increase competition, especially when they face a bewildering array of seemingly insurmountable labor restrictions. And, although it might be desirable to decrease current labor restrictions on competition, this is very unlikely to happen.

However, as discussed at length in this paper, it is possible to attain substantial competition under current labor law and requirements. Although labor requirements do prevent the immediate implementation of unlimited changes, it is possible to implement significant amounts of subcontracting, contracting for service, and similar arrangements for increasing competition, within reasonable time periods.

Finally, it should be realized that attempts to attain more competition often are seen by transit workers as attacks on their job security and bargaining rights. If workers believe this to be true, they and their unions will bitterly oppose the initiatives. Thus, if the changes are not intended to harm job security or the union, this should be exhibited by word and deed. That is, if the competitive initiatives can be structured so everyone gains, or at least so no one loses, they will be more easily accepted.

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REFERENCES

1. *Special Report 217: New Organizational Responses to the Changing Transit Environment.* TRB, National Research Council, Washington, D.C. 1988, 111 pp.
2. Competitive Services Board. *Principles for Increasing Competition in Public Transportation by Recognizing and Dealing Effectively with Labor Requirements.* UMTA, U.S. Department of Transportation, Washington, D.C., 1988.
3. *Public Transit Services: Considerations in Contracting.* American Public Transit Association, Washington, D.C., 1987.
4. J. A. Smith, Jr., K. M. Jennings, and E. C. Traynham. *Labor-Management Relations and Issues in Mass Transit.* National Technical Information Service, Springfield, Va., 1981.
5. R. C. Lieb. *Labor in the Transit Industry.* U.S. Department of Transportation, Washington, D.C., 1976.
6. D. T. Barnum. *From Private to Public: Labor Relations in Mass Transit.* Indiana University Institute for Urban Transportation, Bloomington, 1977.
7. D. T. Barnum. Attaining More Competition in Transit: The Labor Requirements. *Proc., Metropolitan Conference on Public Transportation Research,* University of Chicago Center for Urban Research and Policy Studies, Chicago, Ill., May 29, 1987.
8. *Transit Managers' Handbook: The Grievance Arbitration Process.* American Public Transit Association, Washington, D.C., 1985.
9. G. K. Woodman. *An Analysis of the Labor Issues Raised by the Subcontracting of Public Transit Operations.* Public-Private Transportation Network, Arlington, Va., Sept. 11, 1987.
10. Massachusetts Bay Transportation Authority (MBTA) v. Amalgamated Transit Union Local 589, W. J. Fallon Arbitrator, Sept. 20, 1979.
11. Regional Transportation District (RTD) v. Amalgamated Transit Union Local 1001, J. Smith Arbitrator, March 3, 1977. American Arbitration Association, No. 71-30-0256-76.
12. Fort Wayne Public Transportation Corporation v. Amalgamated Transit Union Local 682, S. B. Goldberg Arbitrator, June 10, 1987.
13. D. T. Barnum. *Handbook for Increasing Competition in Public Transportation by Recognizing and Dealing Effectively with Labor Requirements.* Competitive Services Board and the UMTA, U.S. Department of Transportation, Washington, D.C., 1988.
14. F. and E. A. Elkouri. *How Arbitration Works.* Bureau of National Affairs, Inc., Washington, D.C., 1985.
15. Central Ohio Transit Authority (COTA) v. Transport Workers Union Local 208, M. Handsaker Arbitrator, June 26, 1978. 71 LA 10-18.
16. Transit Authority of River City (TARC) v. Amalgamated Transit Union Local 1447, E. R. Render Arbitrator, April or May, 1987.
17. Transit Authority of River City (TARC) v. Amalgamated Transit Union Local 1447, C. P. Chapman Arbitrator, March 4, 1980. Published in 74 LA 616-620.
18. Chattanooga Area Regional Transportation Authority (CARTA) v. Amalgamated Transit Union Local 1212, E. R. Teple Arbitrator, Nov. 20, 1980.
19. Chicago Transit Authority (CTA) v. Amalgamated Transit Union Local 241, N. M. Gundermann Arbitrator, Aug. 31, 1985.
20. Transit Authority of Lexington-Fayette County (LexTran) v. Amalgamated Transit Union Local 639, J. Krislov Arbitrator, June 3, 1987.
21. Greater Portland (Maine) Transit District (Metro) v. Amalgamated Transit Union Local 714, Judge J. E. Mulcahy Arbitrator, Feb. 4, 1986. American Arbitration Association, No. 71-30-0256-76.
22. South Bend Public Transportation Corporation v. Amalgamated Transit Union Local 996, J. R. Cox Arbitrator, March 31, 1987.
23. Chicago Transit Authority (CTA) v. Amalgamated Transit Union Local 241, R. J. Mueller Arbitrator, April 30, 1982.
24. New York City Transit Authority (NYCTA) v. the Transport Workers Union Local 100, J. E. Zuccotti Arbitrator, Oct. 15, 1986, Oct. 27, 1986, and Nov. 23, 1986.
25. J. Maassen and L. Andrews. *Draft Report on Wisconsin's Legal Constraints re Subcontracting of Transit Services.* Office of General Counsel, State of Wisconsin, Madison, Nov. 5, 1987.
26. R. S. Rubin et al. Contracting Out in the Public Sector. *Midwest Monitor,* Midwest Center for Public Sector Labor Relations, School of Public and Environmental Affairs, Indiana University, Bloomington, Sept./Oct. 1980.
27. Transit Authority of Lexington-Fayette County (LexTran) v. Amalgamated Transit Union Local 639. M. M. Volz, Arbitrator, Dec. 1987. American Arbitration Association, No. 52-30-0332-87.
28. Transportation Management of (Nashville) Tennessee, Inc. v. Amalgamated Transit Union Local No. 1235. J. Clarke, Arbitrator, Feb. 15, 1988.

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Updating Ride Checks with Multiple Point Checks

PETER G. FURTH

A procedure is described for estimating ride checks (ons and offs by stop) by updating old ride checks with recent multiple-point-check data (on, off, and load at selected points). The procedure involves synthesizing an origin-destination (O-D) matrix method and bringing this matrix into agreement with the point-check observations using multiproportional adjustments. Testing on several Los Angeles bus lines indicates how estimation accuracy varies with number of points checked, number of days checked, and length of time period of aggregation. Period-level estimates for periods as small as 20 min are found to have reasonably good accuracy for total boardings, passenger-miles, and maximum load. The procedure can be an economical way to derive ride-check data.

Ride checks, which provide a record of ons and offs by stop along a transit route, are the most complete set of route-level data normally collected by a transit agency. They reveal (a) the total boardings on route and on route segments, (b) passenger-miles, (c) location of the peak load point, (d) maximum load per trip, and (e) average load at the peak load point or any other point of interest. Because of this wealth of information, ride checks are valuable for route and schedule planning, particularly on long or heavy-volume lines, which are conducive to scheduling options such as short-turning, alternating deadheading, zoning, and offering limited stop service (*1*). However, ride checks are expensive to conduct and, consequently, are done infrequently. Ride-check data available to a typical route or schedule planner generally consist of a single day's sample and may be several years old.

Point checks are less expensive to conduct than ride checks. For example, at the Southern California Rapid Transit District (SCRTD), ride checking the entire weekday schedule (covering each trip once) requires 3,350 checker-days, whereas point checking the weekday schedule at peak-load points during 12 daytime hours requires two checkers per point at 132 points, or about 400 checker-days. The passenger use information that point checks provide is limited to ons and offs at the checkpoint and arriving or departing loads. Because they are less expensive, point checks can be measured more frequently, providing the planner with recent and statistically sound estimates. A natural question, then, is how to combine rich but outdated ride-check information with limited but recent point-check information in order to estimate recent ride-check measures. In practice, planners often do the "mental gymnastics" of fitting an old ride check to recent point data. This exercise is extremely difficult to do well, and an updating methodology can provide a mechanism to reconcile these different sources of data into a useful profile. Even if a ride check is recent, it may be suspect if based on a single day's measurement, and combining point-check information from several other days should improve accuracy.

When point checks measure only load at a single point, updating an old ride check is straightforward; the ride check is simply factored up or down to agree with the recently measured load. But if load is measured at several points, or if on and off information is to be incorporated as well, an updating method is not obvious. Simply factoring by an average increase in loads over multiple points presents two problems. First, the resulting estimates will not agree with measured load at any of the points. Second, if three or more points are averaged, they should not necessarily be weighted equally, because if two points are close together their loads will be highly correlated.

MODELING APPROACH

Underlying the on, off, and load information of a ride check is a stop-to-stop origin-destination (O-D) matrix. Ons and offs are row and column totals of the O-D matrix. Likewise, loads are represented in the O-D matrix by rectangular blocks of cells extending to the northeast corner of the matrix, as shown in Figure 1. Although Figure 1 illustrates through load, arriving or departing load could be used instead. O-D volumes can be more easily manipulated than ride-check data, because O-D volumes are independent of one another and, therefore, intrinsically do not need to balance (as do total ons and total offs) or show serial correlation (as do loads). Methods for updating an O-D matrix with summary information such as row and column totals have been widely studied and reported in the literature, having been applied to such areas as updating a bus route O-D matrix with ride-check data (*2*), updating a matrix of intersection turning movements with inflow and outflow totals (*3–5*), updating automobile trip tables with segment flows (*6–8*), and updating regional input-output matrixes with forecasts of regional input and output (*9*). When such a method is used, an O-D matrix can be adjusted to make its row totals, column totals, and block totals agree with observed ons, offs, and loads from point-check data. The modeling approach is, therefore, to estimate or synthesize the O-D matrix underlying the original ride check, to update this matrix to agree with point-check measurements of load and (if available) ons and offs at the checkpoint, and then to reduce the

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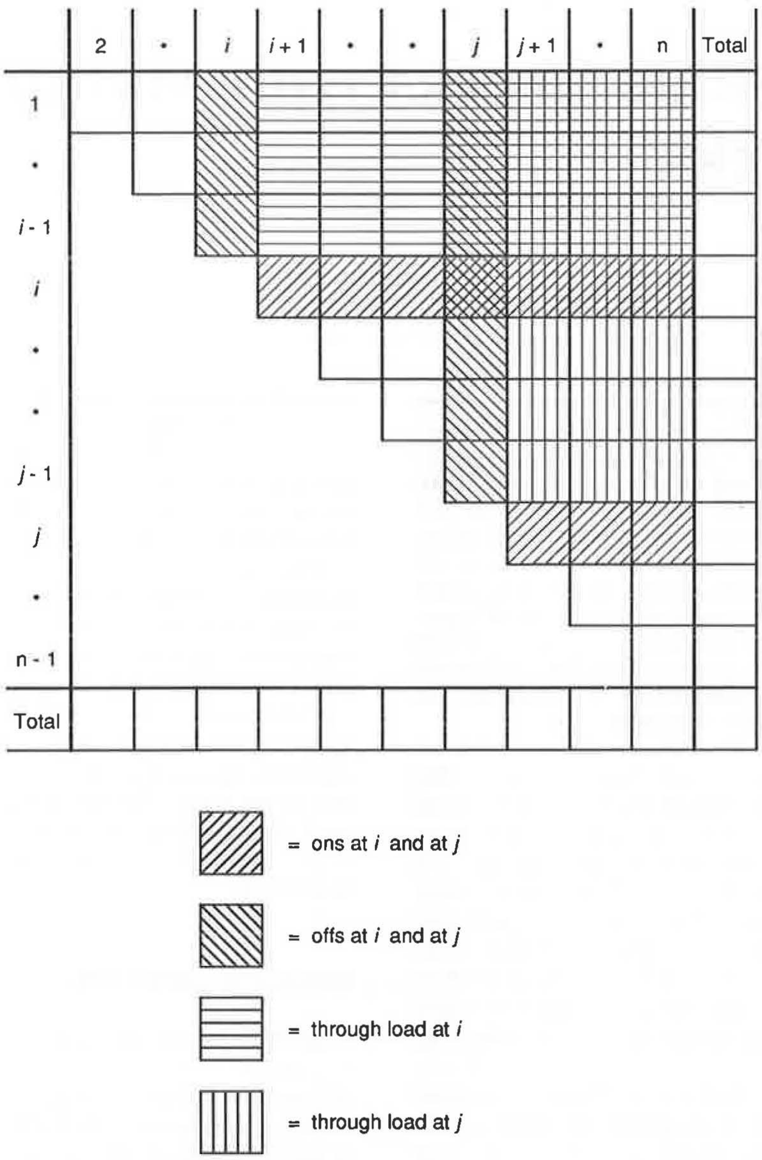

FIGURE 1 Updating with two checkpoints.

updated matrix to its row and column totals, yielding an updated ride check.

Because of space limitations, only an overview of the models will be presented. O-D matrix synthesis is done using a method developed by Tsygalnitzky (*10*). This method was tested with favorable results on two SCRTD lines and is described by Simon and Furth (*11*). The matrix is updated using iterative multiproportional adjustments, as described and tested by Ben-Akiva et al. (*2*) and McNeil and Hendrickson (*12*), using the scalar adjustment derived by Bell (*6*) to make the results constant with respect to scaling of the original seed. Intrasegment travel volumes, which are unaffected by matrix updating (because they are not observed by the point checks), are scaled up or down in proportion to the change in the intersegment volumes beginning or ending in the corresponding segment. More detail is given in the project report (*13*).

APPLICATION TO SCRTD

The updating methodology was applied to SCRTD Lines 30, 45, 53, 92, 117, 152, 200, 209, and 260. Included were heavy-volume lines (peak headway under 5 min) and lighter-volume lines. Existing SCRTD ride-check and line-description computer files were used without modification. Old ride-check data ("seed data") were used to generate seeds. Point-check data were simulated by extracting on, off, and load at designated checkpoints from a set of ride checks taken 1 year later ("new data"). For each line, checkpoints were chosen by SCRTD staff in order of priority so that point checks done at one, two, or three or more stops could be simulated. Because complete ride checks for the new data were available, the accuracy of the updating procedure could be assessed by comparing the estimated ride-check profile to the true profile.

Implementing the updating procedure required resolving some technical issues, which are discussed here. First, it became obvious that each route variation, or branch (as it is called at SCRTD), needs its own seed. A line might have several variations such as the main route, a short line, and minor branching variations. Second, to make the seeds reflect changing travel patterns throughout the day, a separate seed was created for each branch/time-period combination. The day was broken into time periods with boundaries at 6 a.m., 9 a.m., 2 p.m., and 6:30 p.m. The seed matrix for a branch/period combination was found by first accumulating on and off totals by stop from the seed data for that branch and period and then generating an O-D matrix from this period profile.

When a branch/period combination has only a few trips in the seed data, it may be unwise to rely exclusively on those few trips for the seed matrix. Therefore, a method was devised to incorporate information from trips on other branches that served many of the same stops as the branch in question. An O-D matrix was generated for every trip in the seed data, and these O-D matrixes were accumulated by period, summing over all branches. The period O-D matrixes were then normalized to yield the passenger flow between each O-D pair per bus trip serving that O-D pair. When a branch/period combination contained too few trips, its seed matrix was generated by extracting from that period's normalized O-D matrix the cells served by that branch. Branch/period combinations with no trips in the seed data were not analyzed.

EVALUATION PROCEDURES

To evaluate the accuracy of the estimated ride checks, three summary measures were compared to the true values: total boardings, maximum load, and passenger-miles. These items were analyzed separately, recognizing that the updating procedure might estimate some items more accurately than others and that greater accuracy might be desired for some items than for others.

It should be emphasized that "maximum load" is the greatest load on a trip, regardless of where it occurs, and differs from "peak load," which is the load at the point of highest average volume. We did not assess the accuracy of measuring peak load since the point checks are nearly always done at the peak-load point, and so peak load will be estimated without estimation error.

The summary measures were compared at both the trip level and the period level. Because most scheduling and planning decisions are based on time-period averages, rather than on individual trip measures, the research goal was to achieve good agreement between actual and estimated measures at the period level.

MEASURES OF ACCURACY

The measure of error for trip-level quantities is the relative standard error. A relative standard error is calculated for each line/direction/time period as the ratio of the standard error to the mean true value. The standard error is the square root of the average squared difference between the estimated value (of, say, boardings) and the true value.

For period-level quantities there is only one estimated-to-true comparison for each item, and so there is no standard error as such. Therefore, the reported error measure is the relative error, which is the actual error divided by the true value.

To provide summaries of the error measurements for a given item (e.g., boardings), the error measures were averaged over the many line/direction/time-period combinations. The general rules used in aggregating are as follows. To get average relative standard error, standard errors and means are averaged separately, and then the average standard error is divided by the average mean value. To get average relative error, errors and means were likewise averaged separately and then divided. To get average relative absolute error, absolute errors and means were likewise averaged separately and then divided.

NUMERICAL RESULTS

Comparisons by line, direction, and time period were made for all nine lines, using one, two, and three points of point-check data. A typical result, displayed here as Table 1, is that for Line 53, Time Period 2 (6 a.m. to 9 a.m.), which encompasses 23 trips. The Line 53 seeds were taken from 1984 ride checks, whereas the new data are from 1985 ride checks. As shown in Table 1, the estimates of average boardings (127, 119, and 115, using one, two, and three points) show good agreement with the observed mean (121). The prediction of average maximum load is consistently about 5 percent low. The comparison of average passenger-miles, which indicates how well load all along the route is estimated, shows the advantage of using multiple points. Using one, two, and three points, the relative absolute errors drop from 12 percent to near 0 percent.

The trip-level relative standard errors for boardings, using one, two, and three points, are 26 percent, 22 percent, and 16 percent, showing a good deal of estimation error. Trip-level relative standard errors for maximum load are 9 percent, 8 percent, and 8 percent. These rather accurate estimates suggest that maximum loads for this line occur at or very near the checkpoints at which load is observed. The trip-level relative standard errors for passenger-miles are 24 percent, 16 percent, and 7 percent for one, two, and three points, showing very good predictive accuracy for the three-point estimate.

A summary of accuracy statistics from all the line/direction/time-period combinations is shown in Table 2. Of primary importance are the relative errors. To the degree they differ significantly from zero, they indicate an overall tendency in the method to underestimate or overestimate. For route boardings, the relative errors using one, two, and three points are 3 percent, 3 percent, and 2 percent, indicating almost no bias. For passenger-miles, the relative errors again show a slight tendency to overestimate, and improve with each additional point used for the estimation.

The relative errors for maximum load, however, show a small negative bias. This phenomenon is expected since the updating procedure predicts the "most likely" route profile for each trip and, thus, tends to avoid high peaks that randomly occur. Users of this updating procedure should recognize this phenomenon and perhaps compensate by inflating

TABLE 1 ACCURACY OF RIDE CHECK UPDATING—LINE 53, A.M. PEAK

MEASURE	NO. POINTS	BRDGS	PASS MILES	MAX LOAD
MEAN	OBS	121.09	384.62	64.57
	1	126.65	430.15	62.09
	2	119.45	405.23	61.32
	3	114.72	384.36	61.27
RELATIVE ERROR	1	.05	.12	-.04
	2	-.01	.05	-.05
	3	-.05	.00	-.05
RELATIVE ABSOLUTE ERROR	1	.05	.12	.04
	2	.01	.05	.05
	3	.05	.00	.05
RELATIVE STANDARD ERROR	1	.26	.24	.09
	2	.22	.16	.08
	3	.16	.07	.08

TABLE 2 RIDE CHECK UPDATING—SUMMARY

NO. TRIPS: 1501

MEASURE	NO. POINTS	BRDGS	PASS MILES	MAX LOAD
MEAN	OBS	90.58	298.90	40.06
	1	93.65	308.09	36.59
	2	93.59	308.35	37.98
	3	91.69	300.22	37.79
RELATIVE ERROR	1	.03	.03	-.09
	2	.03	.03	-.05
	3	.02	.02	-.05
RELATIVE ABSOLUTE ERROR	1	.12	.10	.12
	2	.08	.06	.07
	3	.06	.05	.07
RELATIVE STANDARD ERROR	1	.31	.27	.25
	2	.22	.17	.16
	3	.18	.13	.13

the estimates slightly. Average load at a peak point, however, should not be biased in this way.

Relative absolute errors in the estimates of period-level averages are also displayed in Table 2. For route boardings, the relative absolute errors using one, two, and three points are 12 percent, 8 percent and 6 percent. The passenger-mile and maximum-load errors are comparable. These results suggest that the updating procedure is quite accurate at estimating time-period-level averages.

Also displayed in Table 2 are the relative standard errors of trip-level items. For route boardings, aggregated over all lines and time periods, these errors are 31 percent, 22 percent, and 18 percent, using one, two, and three points. Passenger-mile and maximum-load results are comparable. These results show that it would be improper to place much confidence in a ride check estimated for a single trip. Indeed, accuracy at this level of detail cannot be expected from any updating procedure using only 1 day of observation because of the high day-to-day variability in passenger activity at the trip level. However, by doing point checks on several days and averaging the results, it may be possible to obtain a reliable estimate of trip-level activity at moderate cost.

The same comparisons were performed using peak-period data only. The results are similar, appearing to be a little bit better on the whole. Line/direction/time periods were then grouped according to their average trip boardings (below 50, above 100, and in between) to see if any one group was estimated with better or worse accuracy. Little significant difference was found. Details of these analyses are given in the project report (*13*).

Because SCRTD's Scheduling Department bases headways on 20-min averages, estimates were also made for 20-min periods between 6 a.m. and 9 a.m. in both directions of Line 45. No trips were observed in one direction in one of the 20-min periods, yielding a total of 17 periods, encompassing 57 trips. Updating was tested using one, two, three, and four points of point-check data. Two of these cases are summarized in Table 3. The quantity of primary concern, maximum load, is estimated very well with three points. The maximum error is 13 percent, and all but two periods had errors below 10 percent. Passenger-miles are estimated almost as well; boardings are estimated a little worse, with a few periods having errors above 15 percent. Estimates based on a single point check, by contrast, are extremely unreliable, with errors above 10 percent being more the rule than the exception. Maximum load for one period was estimated at 29.9 when the true value (averaged over two trips) was 67, indicating that information from a single point was insufficient to detect an unusual crowding pattern in this period. Line 45's need for multiple, as opposed to single, point checks is reasonable because it goes through the downtown, with heavy loads on both sides of downtown.

ACCURACY VERSUS NUMBER OF POINTS

Estimation accuracy was tested on Line 30 using one to nine points of point-check data. The points were selected in order of priority by SCRTD staff. The data encompass 315 trips over an entire day in both directions. Figure 2 shows that the overall estimation bias is small (within 5 percent) for all three quantities of interest for any number of points and that there is little improvement after the fourth point. Oddly, the passenger-mile bias worsens beyond four points; however, it never exceeds 5 percent in magnitude.

Figure 3 shows how trip-level standard errors improve with the number of points. The biggest gain is in the first four points, although improvement continues until about the seventh point, where the standard errors are between one-half and one-fifth of the size of the standard errors based on a single point.

TABLE 3 ACCURACY OF 20-MIN-PERIOD ESTIMATES—LINE 45

	Periods With Error < 10% (out of 17)	Periods With Error < 15% (out of 17)	Worst Case Error
a. Using 3 points			
Boardings	11	14	23%
Pass.-mi	15	17	14%
Avg Maximum Load	16	17	13%
b. Using 1 point			
Boardings	4	6	42%
Pass.-mi	7	11	36%
Avg Maximum Load	11	12	55%

These two figures together indicate that the systematic component of estimation error is rather small, whereas the random component, which tends to balance out when averaged over many trips, can be large but reduces with more information about each trip.

It is difficult to generalize these results into guidance for how many points ought to be counted. To prevent significantly sized markets from going unobserved, it would seem reasonable to station checkers 4 to 5 mi apart, because the average unlinked trip length on the system is about 3 mi. On route segments with average trip distance smaller, and passenger activity more variable in its distribution, closer spacing is warranted. On route segments with average trip distance larger and passenger activity less variable in its distribution, farther spacing is warranted.

The lower cost of point checks suggests the possibility of doing them for several days and averaging the estimates made for those days. Because the desired measure for planning and scheduling is *average* passenger activity, even a single day's ride check is only an estimate, and so the possibility exists that a multiday estimate based on point checks may be more reliable than a single day's ride check. Averaging together samples taken on *n* days will reduce random error and variability components inversely with the square root of *n*; however, systematic error or bias components will be unaffected.

Much of the error in a period-level estimate can be attributed to systematic error, which arises because all of the trips in a given period are estimated with the same seed. A reasonable and conservative judgment is to attribute 80 percent of the period-level squared error to systematic error. The same degree of systematic error applies to trip-level estimates. The balance of the estimation error is considered random.

Besides estimation error, another source of error is day-to-day variation. Because multiday ride checks were not available for this study, this type of variation could not be measured. However, other studies indicate a route/direction/time-period day-to-day variation (i.e., coefficient of variation) in trip-level boardings of 20 percent or higher, whereas the day-to-day variation of period-level boardings is around 8 percent. The same figures can be applied to passenger-miles.

Based on these assumptions, and using the average estimation errors reported in Table 2, expected standard errors based on multiple days of updating with point checks using two and three points were calculated for selected items and are displayed in Tables 4 and 5. For comparison, the standard errors expected from using a day of ride checks as a daily average are shown as the day-to-day variation.

These results show that a single day's estimate using the updating procedure is, naturally, worse than a single day's measurement using a full-ride check. Using three points, standard errors are about 25 percent greater (e.g., a relative standard error of 10 percent instead of 8 percent); using two points, errors are about 38 percent greater. There is, therefore, a small but significant loss in accuracy from substituting

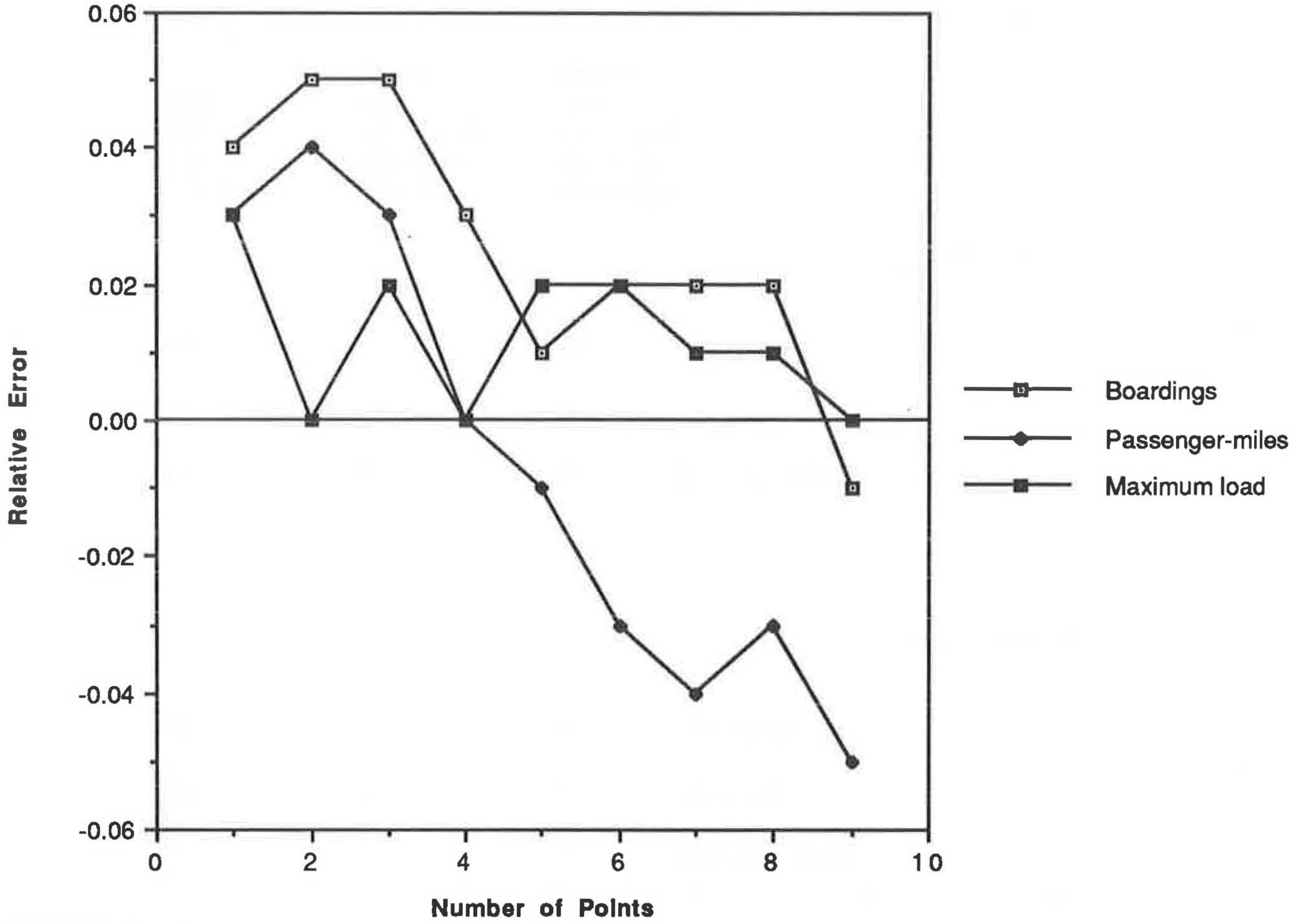

FIGURE 2 Relative error versus number of points.

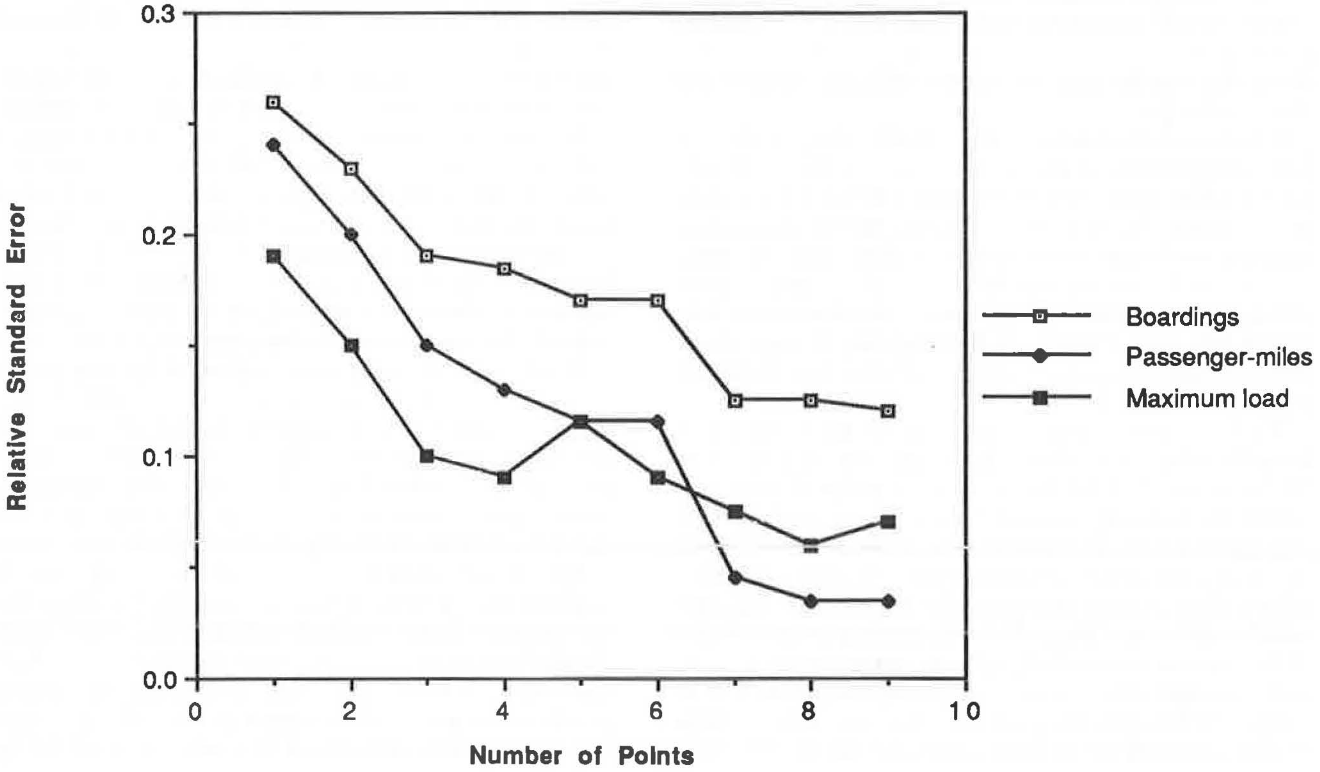

FIGURE 3 Relative standard error versus number of points.

TABLE 4 MULTIPLE-DAY COUNT OF RELATIVE ERRORS USING THREE POINTS

	Day-to-day Variation	Random Est'n Error	Total Random Variation	Sytematic Est'n Error	Relative standard error		
					1 day	2 days	3 days
Period Boardings	0.080	0.027	0.084	0.054	0.100	0.080	0.072
Trip Boardings	0.200	0.172	0.264	0.054	0.269	0.194	0.161
Period Pass.-Mi	0.080	0.022	0.083	0.045	0.094	0.074	0.066
Trip Pass.-Mi	0.200	0.122	0.234	0.045	0.239	0.172	0.142

TABLE 5 MULTIPLE-DAY COUNT OF RELATIVE ERRORS USING TWO POINTS

	Day-to-day Variation	Random Est'n Error	Total Random Variation	Sytematic Est'n Error	Relative standard error		
					1 day	2 days	3 days
Period Boardings	0.080	0.036	0.088	0.072	0.113	0.095	0.088
Trip Boardings	0.200	0.208	0.289	0.072	0.297	0.216	0.181
Period Pass.-Mi	0.080	0.027	0.084	0.054	0.100	0.080	0.072
Trip Pass.-Mi	0.200	0.161	0.257	0.054	0.262	0.189	0.158

a 1-day multiple-point check for a 1-day full ride check. However, since much of error is day-to-day variation (which affects both ride and point checks), additional days of point checks lower the standard errors of the estimates. With 2 days of point checks using three points, with ride checks estimated for each day separately and then averaged together, the resulting standard errors are less than those standard errors associated with 1 day of full-ride checks. With 3 days of point checks, standard errors are smaller still. Using two points instead of three is not as accurate, especially in estimating period boardings where even with 3 days of point checks the error is still worse than with a single day of ride checks.

EFFECT OF MEASUREMENT ERROR

One problem with a point check-based methodology is that measurement errors can be significant. In Table 6 the expected levels of accuracy of using a three-point check have been revised to account for measurement error as well as the error sources used in Table 4. The assumptions underlying this adjustment are as follows:

- Standard error for load measurement of an individual trip is 13 percent (as reported in an internal SCRTD study).
- Averaged over many trips and all checkers, loads are systematically undercounted or overcounted; the direction of the bias is unknown (otherwise SCRTD could simply adjust load figures accordingly). A magnitude of 3 percent was used.
- Each individual checker, averaged over many trips, has a different systematic error. An average systematic error of 6 percent was assumed.
- When a point check is done at *m* points for *n* days, it can be assumed that the same checker will be assigned to a point for the *n* days. (The alternative assumption, i.e., that checkers change location from day to day, would lead to better accuracy estimates.)

TABLE 6 RELATIVE ERRORS USING THREE POINTS, ACCOUNTING FOR MEASUREMENT ERROR

	overall systematic measurem't error	individual systematic measurem't error	individual total error	day-to day variation	Relative standard error from n days of updating		
					1 day	2 days	3 days
Period Boardings				0.08	0.12	0.10	0.09
Trip Boardings	0.03	0.06	0.13	0.20	0.27	0.20	0.17
Period Pass.-Mi				0.08	0.12	0.09	0.08
Trip Pass.-Mi	0.03	0.06	0.13	0.20	0.26	0.19	0.16

- Error components for a given checker are assumed independent.

The net effect of measurement error, combined with all the other sources of variation, is to raise relative errors somewhat, making it more important that estimates be based on several points and on several days if possible.

IMPLEMENTATION ISSUES

Incorporating ride-check updating into a systematic data collection program requires a thorough review of a transit system's data needs followed by the design of a statistically sound program that most economically meets these needs. Difficult-to-quantify trade-offs are often necessary. Data needs beyond the ridership profiles discussed in this paper must be addressed, such as route revenue and running time data, which can better be determined using a ride check than using multiple-point checks with ride-check updating. The general problem may be framed thus: for a given amount of data collection resources, how to allocate these resources to best meet the transit agency's objectives using available data collection and analysis techniques. Should ride check updating be done every other year, or 2 years out of 3, or 9 years out of 10 (with real ride checks done in the other years)? Should ride check updating be done on all lines, or only some lines? at all times of day, or only daylight times or peak periods? How many points should be checked per line, and should multiple-day point checks be done? Some design questions cannot be properly addressed without more research. For instance, seeds that are more than 1 year old have not yet been tested. The method should also be tested in other cities and on different types of routes. Various sampling strategies can also be tested.

Some trade-offs can be made using the results reported in this paper. For example, if it were determined, based on the Table 6 results, that a three-point check must be conducted on 2 days to provide sufficient accuracy to substitute for a full-ride check (i.e., riding every trip on a line for 1 day), would this substitution be economical? A full ride check requires one checker per bus. This requirement is the same whether a ride check is desired for one direction or both. The checker requirement for point checks depends on the extent to which a checker can monitor multiple lines and two directions. Because of the width of Los Angeles streets and the heavy bus volumes in many locations, it is common for checkers to monitor only one direction. With the conservative assumption made that only one line will be monitored at a time, point checks require one checker per point per day per direction. To do point checks at three points on 2 days will, therefore, require up to 6 checkers for a peak-direction ride check and up to 12 for ride checks in both directions. A margin should be added to account for analysis costs and complications. Estimates based on point checks will therefore yield a cost savings if the line uses more than 15 buses during the time period of interest or 8 buses if only a peak direction profile is needed. On lines and during time periods when fewer buses are operated, a ride check will be more cost-effective. At times and locations where a checker's safety is of serious concern, ride checks can continue to be the main source of data.

Some objections to using such a methodology can be overcome creatively. For example, if running time data are needed over the entire line, adding point checks at the route endpoints can meet this need. Also, because multiple-point checks are blind to many incidents such as detours and accidents that cause traffic delays, it may be wise to have an occasional ride checker verify whether the running time data collected with multiple point checks are valid. These additional costs must be reckoned with in designing the data collection program, of course.

A preliminary implementation study has been conducted for SCRTD. Validation testing is now under way within the agency to assess the procedure's accuracy on several additional lines. Efforts are also being considered to see whether point-check measurement error can be materially reduced. At the same time, efforts are under way to automate point-check data collection using hand-held devices. If successful, these efforts will make updating a more attractive option. Full implementation, if approved, will require a significant amount of computer programming and documentation to provide the flexibility of dealing with different forms of data input, data error checking, minor routing changes, and so on. Testing on different routes may also be needed to provide more guidance in the selection of checkpoints.

CONCLUSIONS

A methodology for updating ride checks using multiple-point checks has been developed and tested. Its accuracy when using a 1-day, 1-year-old ride check for the seed is not as good as taking a new ride check, but if point checks can be repeated on several days, the estimates can be of comparable accuracy. Ride-check updating can offer an economical way to acquire ride-check information on high-frequency lines, as well as an inexpensive way to get better use out of point-check data that may now be routinely collected. There are significant implementation and research issues still to be resolved before this methodology is adopted as a regular part of a data collection program, but it seems to offer many benefits.

REFERENCES

1. P. G. Furth and F. B. Day. Transit Routing and Scheduling Strategies for Heavy Demand Corridors. In *Transportation Research Record 1011*, TRB, National Research Council, Washington, D.C., 1985, pp. 23–26.
2. M. Ben-Akiva, P. Macke, and P. S. Hsu. Alternative Methods to Estimate Route Level Trip Tables and Expand On-Board Surveys. In *Transportation Research Record 1037*, TRB, National Research Council, Washington, D.C., 1985, pp. 1–11.
3. E. Hauer, E. Pagitsas, and B. T. Shin. Estimation of Turning Flows from Automatic Counts. In *Transportation Research Record 795*, TRB, National Research Council, Washington, D.C., 1981, pp. 1–7.
4. A. Mekky. On Estimating Turning Flows at Road Junctions. *Traffic Engineering and Control*, Vol. 20, No. 10, 1979, pp. 486–487.
5. H. J. Van Zuylen. The Estimation of Turning Flows on a Junction. *Traffic Engineering and Control*, Vol. 20, No. 11, 1979, pp. 539–541.
6. M. G. H. Bell. The Estimation of an Origin-Destination Matrix from Traffic Counts. *Transportation Science*, Vol. 17, No. 2, 1983, pp. 198–217.
7. I. Geva, E. Hauer, and U. Landau. Maximum Likelihood and Bayesian Methods for the Estimation of O-D Flows. In *Transportation Research Record 944*, TRB, National Research Council, Washington, D.C., 1983, pp. 101–105.
8. H. J. Van Zuylen and L. G. Willumsen. The Most Likely Trip Matrix Estimated from Traffic Counts. *Transportation Research*, Vol. 14B, 1980, pp. 281–293.
9. M. Bacharach. *Biproportional Matrices and Input-Output Change*. Cambridge University Press, Cambridge, England, 1970.
10. S. Tsygalnitsky. *Simplified Methods of Transportation Planning*. M.S. thesis in civil engineering. Massachusetts Institute of Technology, Cambridge, 1977.
11. J. Simon and P. G. Furth. Generating a Bus Route O-D Matrix from On-Off Data. *ASCE Journal of Transportation Engineering*, Vol. 111, No. 6, 1985, pp. 583–593.
12. S. McNeil and C. Hendrickson. A Note on Alternative Matrix Entry Estimation Techniques. *Transportation Research*, Vol. 19B, 1985.
13. P. G. Furth. *Enhancing Patronage Estimation and Line Performance Monitoring Procedures*. Final Report for the Southern California Rapid Transit District, Multisystems, Inc., Cambridge, Mass., 1988.

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Producing Section 15 Service-Consumed Data: Challenge for Large Transit Authorities

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Large transit authorities encounter many difficulties collecting the operating statistics required for UMTA Section 9 funding. Transit agencies that operate rail and bus systems 24 hours per day, 365 days per year must gather statistics from a universe of riders that is sometimes difficult to capture through UMTA-suggested random sampling. This paper examines how the Chicago Transit Authority (CTA) is meeting the challenge of collecting Section 15 service-consumed data from a large, dynamic transit system. The CTA method of determining annual unlinked trips and passenger-miles for the bus and rail systems is presented here. This includes the resources required to assign and monitor data collection efforts as well as problems regularly encountered in-the-field by data collection personnel. CTA's stratified rail sampling plan and the needs of large transit systems are discussed along with suggestions for more efficient data gathering techniques.

All U.S. transit systems report annual ridership and passenger-mile statistics to UMTA to qualify for Section 9 funding. UMTA Circular 2710.4 suggests that a sample size of 208 fixed-route bus trips per year will yield operating data that satisfy the specified confidence and precision levels of 95 percent and ±10 percent respectively. This paper examines the methodology used by the Chicago Transit Authority (CTA) to meet the challenge of collecting service-consumed data for both bus and rail service.

Since the UMTA circular exists as merely a guideline delineating data collection requirements for all transit authorities (TAs), we will discuss alternative sampling methodologies that conform to UMTA specifications but that are more appropriate for CTA and perhaps other large agencies. Evidence is presented to suggest that the collection of an equal number of good observations is considerably more difficult for large TAs than for smaller transit systems—if quality control is maintained. Data gathering procedures must be more sophisticated to acquire statistically valid results from a system that operates 24 hours per day, 365 days per year. Beginning with sample design, we will show how single random sampling, without stratification, may misrepresent ridership statistics of large bus and rail systems. The 1988 CTA stratified rail sampling plan will be presented along with January through June sample results. Random trip selection, scheduling, and field problems encountered during the entire data gathering process will be examined as well as administrative and quality-control difficulties such problems create. And finally, suggestions for additional, more-efficient data gathering methods will be discussed.

SAMPLE DESIGN

Bus System

UMTA Circular 2710.4 (*1*) details the approved data gathering methodology for all fixed-route bus systems. A sample of 208 bus trips randomly selected and sampled weekly throughout the reporting year is suggested to adhere to 95 percent confidence levels at ±10 percent relative precision. The recommended revenue-based method estimates the number of annual unlinked trips and passenger-miles from the fare revenue collected and the passenger-miles observed during the 208 sample trips. CTA, however, has chosen to use the trip-length statistic, rather than the revenue/unlinked trip statistic, to estimate passenger-miles, although revenue data are still collected for comparative purposes.

Precision of ±10 percent may be adequate for UMTA reporting of unlinked trips, but it is not sufficient for CTA's in-house purposes. A 10 percent error in annual unlinked trips totaling over 400 million is greater than the year-to-year change in ridership. Precision of only ±40-million riders provides a poor basis for predicting operating income. Consequently, CTA uses a full-count of unlinked trips, counting every single passenger as he or she boards a bus.

All CTA buses are equipped with General Farebox Industries (GFI) electronic fareboxes capable of tabulating the number of boarding passengers by the fare medium presented or deposited. Bus operators register each boarding passenger by pressing the appropriate farebox key corresponding to the fare payment presented. The fareboxes used by CTA since 1988 electronically transit these counts to the central farebox computer each day. In this manner, CTA can monitor ridership daily, weekly, and monthly, by route, fare category, payment method, and so on. And, since the bus operators have proven to be 98 percent accurate in keying in boarding passengers, the full-count method has proven much more efficient and precise to CTA management than the revenue-based method of estimating unlinked trips.

The Section 15 report of 1987 was the first in which CTA reported unlinked trips based on the full count taken from

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the fareboxes. In 1986 the revenue-based method was reported, even though full-count data were available. The 1987 and subsequent Section 15 reports use the sample trips only for the purpose of calculating the statistic of average trip length. This number is then multiplied by the number of unlinked trips (from the farebox) to estimate passenger-miles.

Because Section 15 sample trips for CTA purposes are used only to determine average trip lengths, a simple random sample, as suggested by UMTA, could tend to misrepresent average trip length because of the randomness in the selection process. Because the sampling unit in the revenue-based method is a bus trip, the universe from which a random trip is selected is the daily schedule of all bus trips.

At CTA, as at other large agencies, buses are in operation around-the-clock, even though over 50 percent of all rides occur during the 6 hr of the weekday a.m. and p.m. rush periods. Bus operations are sized to carry the peak passenger demands. However, to maintain service quality in the off-peak hours, bus trips are not scheduled in direct proportion to ridership. When selecting random sample bus trips, the chance of picking a midday or evening trip is higher than the proportion of riders or passenger-miles carried, because the buses operating in those time periods transport a lower proportion of CTA's bus riders (see Table 1). In addition, because average trip lengths are longer during a.m. and p.m. rush periods as a result of people commuting longer distances to and from work, a disproportionate number of midday sample trips will misrepresent the average trip length of the majority of system bus riders.

The weekday on which bus trips are to be sampled is also randomized, as suggested by UMTA. However, CTA has performed statistical analyses on the data base of 1987 sample bus trips that negate the need for weekday randomization. Average trip lengths collected on different weekdays in 1987 were compared for statistically significant differences using the general linear model procedure of the Statistical Analysis System (SAS). Analyses of variance between the means collected in each time interval were analyzed via the *t*-test (least significant difference), the Tukey studentized range test, and the Duncan multiple range test. All results revealed no significant difference in the mean trip length at 95 percent confidence—regardless of the weekday on which the data were collected (see Table 2). It is expected that the 1988 bus sample trip results will also reflect this finding.

TABLE 1 CTA BUS SYSTEM LOAD FACTORS BY TIME ON WEEKDAY

Weekday Time Period (hours)		1987 Load Factors[a]	Percentage of Daily Unlinked Trips
A.M. Peak	(0600–0900)	16.9	24.1
Midday	(0900–1500)	12.9	29.0
P.M. Peak	(1500–1800)	19.2	26.1
Other	(1800–0600)	11.6	20.8

[a] Passenger-miles/revenue-vehicle-miles.

TABLE 2 DUNCAN'S MULTIPLE RANGE TEST

Duncan[a] Grouping	Mean	No. of Trips	Day
A	2.29	40	Friday
A	2.27	31	Thursday
A	2.16	23	Wednesday
A	2.05	42	Monday
A	2.04	38	Tuesday

NOTE: Variable: 1987 bus average trip length. alpha = 0.05; degree of freedom = 1.69; mean of square error = 1.05.

[a] Means with the same letter are not significantly different.

Rail System

CTA's rail system sample design evolved in a different way. The 1986 Section 15 report was the first one in which UMTA required both rail and bus passenger-miles to be collected in the same reporting year. Previous rail passenger-mile data had only been gathered periodically because of the relatively great expense and unavailability of staff time. The resulting statistic of average rail passenger trip length was then used in Section 15 reports for several subsequent years.

Part of what makes rail passenger-miles more challenging to gather is the absence of any UMTA-suggested sampling plan. Therefore, most rail systems, including CTA, have developed their own customized rail sampling plans to meet UMTA's statistical standards—95 percent confidence, ±10 percent precision, sampled weekly throughout the year.

Rail ridership at CTA has been measured by fare collecting employees (ticket agents and conductors) since the mid-1970s yielding a full-count of unlinked trips daily. Nearly all passengers paying with cash, transfer, or pass must go through a turnstile, either manually operated or automated, before gaining access to the rail system. (In times of low traffic, conductors collect fares on board, which accounts for approximately 2 percent of annual boardings.) Therefore, as with the bus system, Section 15 sample trips are only required to determine average passenger trip length.

Average trip length is determined by assigning data collectors to ride in one rail car of a sample trip from terminus to terminus counting the number of passengers boarding and alighting at each station. Passenger loads are calculated and multiplied by the distances between stations to determine passenger-miles. The sum of the passenger-miles divided by the sum of boarding passengers (unlinked trips) is the average trip length for the sample trip.

Before the 1988 fiscal year, CTA designed its current rail sampling plan and submitted it to UMTA for approval. As mentioned earlier, simple random samples may not adequately represent ridership on a system that operates 24 hr/day. For example, ridership behavior in the early morning hours is unlikely to resemble that of the p.m. rush period. Therefore, a stratified sampling plan was selected that compensates for shifts in observed passenger-miles that are a function of the time of day. This methodology provides a more valid, cross-sectional profile of CTA rail riders.

The strata used for this plan are based on the following time of day and day of week intervals: a.m. peak, midday, p.m. peak, other (weekday), Saturday, and Sunday. The total sample is allocated among the mutually exclusive strata based on the proportion of the total unlinked trips boarding during the time period relative to each stratum. Worst-case sample variances from 1985 were used as a historical reference to calculate the following sample size:

$$n = (z^2/r^2)c^2 \qquad n = 152 \text{ sample trips}$$

where

Z = 95 percent confidence Z value of 1.96,
r = relative precision of ±10 percent, and
c = coefficient of variation—estimated at 0.628 (worst-case variance from 1985 rail data).

Because this sample size calculation is based on the minimum requirements specified by UMTA, CTA has increased the sample design for 1988 to 100 rail trips to compensate for any unforeseen sampling error that may arise from the implementation of a new sampling plan. Even at 300 samples, this number is less than half the number of samples taken in 1987.

The CTA stratified rail sampling procedure is designed so that sample sizes may change relative to observed sample variances. In other words, the learning curve process will increase precision so that sample sizes in subsequent years may be reduced and still meet UMTA confidence levels and precision requirements. The 1988 year-to-date statistics show CTA rail sample trips to have ±4 percent precision at a 95 percent confidence interval after only 158 sample trips.

As with the bus system, various techniques for testing analysis of variance have been applied to the year-to-date rail sample results. As expected, no significant differences were detected in average trip length data collected on various weekdays. Significant differences in mean trip length were detected, however, when comparing means collected during different time-of-day intervals. This analysis further confirms that time of day is the most appropriate variable on which the strata for this sampling plan should be based. Year-end testing of these data is expected to reaffirm these findings and to serve as justification for slight modifications in the 1989 sampling scheme. In addition, special counts will be scheduled to continually verify time-of-day ridership proportions and to analyze new ridership trends by corridor, rail line, station, and time of day.

APPLYING THE METHODS

Trip Selection

Once the appropriate sample sizes have been determined, the practical aspects of implementing the plan come into play. Since both bus and rail sampling plans are trip-based, the sample selection process now moves to the schedules.

Bus

The bus sampling plan suggested in UMTA Circular 2710.4 (the current method used by CTA) calls for 208 bus trips sampled throughout the reporting year. But because bus schedules change periodically, sample trips cannot be selected too far in advance. Thus, it is a crucial aspect of the sampling process to have up-to-date and accurate schedules. In a large system such as CTA's, this seemingly simple requirement can become quite complex. Just finding a place to physically locate schedules for over 26,000 daily bus trips operating over 133 bus routes on weekdays is difficult, and it is even more difficult to make sure that the schedules you have are all up-to-date.

Currently, all random trip selections are primarily a manual process based on these schedules. The mere size of this 26,000 weekday trip data base (plus 20,000 Saturday trips and 18,000 Sunday and holiday trips) has caused problems in the quest for computerization. However, this process is moving forward, and currently a personal computer is used to select the random trip number, which is then manually looked up in the schedules. Continual dialogue with the CTA Schedules Department is necessary to be alerted of changes in schedules, dates, times, routes, and so on. Often timetable changes will force the cancellation of scheduled Section 15 sample trips, and replacements must be selected.

CTA presently selects bus sample trips just before new bus schedules go into effect for ease in work-load scheduling and to minimize the effects of schedule changes. On average, 2 full days of staff time are dedicated to bus trip selection each month. The 208 annual trips are divided into about 18 trips per month. Sample trips are scheduled each week of the month based on the randomization of the day of the week on which the sample is to be taken.

Rail

Selecting trips for the rail system is not quite as cumbersome as it is for the bus system because daily trips are just over 2,100 in number. Samples are selected from each time-of-day/day-of-week stratum based on the proportion of unlinked rail trips occurring in each time period. Those proportions are indicated in Table 3.

A random sample of rail trips based on these proportions is selected on a monthly basis. With a total annual sample size of 300 rail trips, about 6 trips are sampled weekly. The day of the week on which the sample is to be collected, as well as the car of the train in which the data collector should ride, are also randomized. The selected trips are manually located in the appropriate schedules and then assigned. Obviously, constant dialogue is also critical with the rail schedules department to maintain current copies of schedules and to be aware of any pending changes in service. The process of selecting rail sample trips each month takes about 6 hr of staff time; computerization may also speed this process in the not-too-distant future.

Collecting Data

The process considered thus far uses considerable management and staff time to prepare lists of randomly selected trips.

TABLE 3 CTA RAIL PLAN STRATIFICATION

Stratum	Time Interval	Proportion of Total Sample (%)
Weekday		
A.M. Peak	0600–1859	23
Midday	0900–1459	22
P.M. Peak	1500–1759	28
Other	1800–0559	14
Saturday	0001–2400	8
Sunday	0001–2400	5

Beginning in 1987 data collection has been done by a staff of field data collectors who are not limited by standard traffic-checking work rules and practices and are hired at up to $25,000/year to collect these data. Work schedules are prepared weekly for this field staff from lists of randomly selected trips. This change in method eliminated problems experienced in 1986 and 1987 when a small staff was available for data collection only part time, limiting its effectiveness. The use of full-time data collectors observing more stringent field procedures has resulted in much better control over the data-collecting process. This has allowed CTA to meet its data-collecting objectives in a more regular manner.

Since the beginning of 1988, weekly work schedules have been written for a fluctuating staff of one to three data collectors. Work schedules made from lists of randomly selected bus and rail trips are augmented by work orders, assignment sheets, and data-collecting forms. Other field work and office assignments are completed, provided that they do not interfere with Section 15 data collection.

Integrated Scheduling of Bus and Rail Trips

Combining bus and rail trip assignments achieved substantial savings in the number of person-days required to collect data. Section 15 data collection for CTA's bus and rail systems was fully integrated in the first 6 months of 1988. This change not only helped to justify the use of full-time data collectors but was consistent with the needs of the 1988 sampling plan.

Integration of bus and rail trips significantly reduced the minimum number of person-days that would have been required to collect these data had separate staffs been used as in 1987 (see Table 4).

Integrating bus and rail scheduling is advantageous because trips that are randomly selected by day of the week often cluster in ways that make combining several trips into a single day's work schedule impossible. For example, the May 1988 rail list of 33 sampled trips required a minimum of 21 person-days to complete.

May's Tuesday trips help to explain why so many person-days are necessary. The eight rail trips listed for Tuesday required 7 person-days to complete because only one observation could be done on the same day as any other rail piece.

Weekly Work-Based Scheduling Difficulties

The process of writing weekly work schedules is a complex networking task. Factors in efficient scheduling are up-to-date knowledge of the bus and rail systems; clear understanding of work rules, scheduling policies, and other limitations; awareness of missed trip rates; and other miscellaneous factors that may affect trips.

Some scheduling difficulties stem from the size and complexity of CTA's bus and rail systems, which operate 24 hr/day over more than 250 sq mi. In assembling work days from randomly selected work pieces, considerable travel time between segments frequently prevents the assignment of otherwise compatible work assignments.

To minimize time lost traveling to and from the general office in downtown Chicago's Merchandise Mart, data collectors collect and drop off work pieces only once a week. Sometimes a week or more will go by before a trip can be verified as being missed. This limits the number of trips available to be scheduled and lengthens the time required to write work schedules.

Because trips are missed regularly, limited overscheduling is done so that after voided and missed trips are eliminated the total number of valid trips completed is the number required. Also considered are the completion rates of the data collectors available to work in that week. These may alter the number of trips assigned.

Table 5 shows the rate at which data collectors were successful in locating and riding the assigned run or its follower. Riding a scheduled run's immediate follower to the same destination was counted as a successfully completed trip. A stricter rule allowing only the selected trip would reduce completion rates by at least 10 percent.

Scheduling Challenges

Two scheduling problems are imposed by the suggested UMTA guidelines. First, gathering data each week causes great inefficiencies in the collection of the requisite 208 bus trips. Second, the time needed to learn that a selected trip worked in the field is invalid is often considerable.

In the first half of 1988 approximately 13 percent of scheduled bus trips were missed. Some of these misses were a result of problems encountered by data collectors using CTA to travel from one assignment to another. Other trips were cancelled, turned back, or delayed to such an extent that a data collector would have to miss a substantial amount of other assigned work to wait for that trip.

This problem is typical of a large property, which may have as many as 35 buses operating on 30 or more miles of a route at any one time. If traffic is slowed or other problems occur,

TABLE 4 NUMBER OF DAYS ON WHICH PASSENGER-MILE DATA WERE COLLECTED, JANUARY–JUNE 1988

Month	Bus	Rail	Bus Days + Rail Days	Bus Days Combined With Rail Days	Days Saved (%)
January	20	19	39	33	15.4
February	24	22	46	22	52.2
March	6	13	19	15	21.1
April	13	16	29	19	34.5
May	20	24	44	26	40.9
June	12	20	32	27	15.6
Total	95	114	209	142	32.1

TABLE 5 DATA COLLECTION COMPLETION RATES, JANUARY–JUNE 1988

Collector	Assigned	Completed	Missed	Complete (%)
Bus Only				
A	72	66	6	91.7
B	34	26	8	76.5
C	13	10	3	76.9
D	19	18	1	94.7
Total	138	120	18	87.0
Rail Only				
A	118	109	9	92.3
B	48	40	8	83.3
C	1	1	0	100.0
D	19	17	2	89.4
Total	186	167	19	89.8
Bus and Rail Combined				
A	190	175	15	92.1
B	82	66	16	80.4
C	14	10	3	71.4
D	38	35	3	92.1
Total	324	287	37	88.6

a data collector waiting in the field often has no way to know whether or when the scheduled run will arrive.

A method using schedule-based trip selection as the basis for the data collection process, that is, a method in which time, route, and direction are the basis for trip selection rather than the requirement that a specific run be met, would greatly enhance the data collection process and make trips selected more truly representative. For example, a data collector is assigned to collect data on a bus trip, Run 362, scheduled to leave for the 95th/Dan Ryan rapid transit terminal at 0733. Instead of waiting for Run 362, which has been running 45 min behind schedule because of a freight train delay at the beginning of its run, the data collector boards whatever bus is going to that same destination nearest 0733. In this way, the data collector would be measuring the average trip length of the passengers traveling at the time the trip was scheduled instead of measuring passengers traveling considerably later.

The second challenge, delay, which occurs in determining whether trips are valid, can be considerable. If a data collector knows that he or she has a missed or voided trip, sometimes that trip can be reincorporated into the next week's work schedule. However, more often than not, the data collector either believes that the correct trip was worked or fails to notice a problem with the trip so that a minimum 1-week delay occurs before a trip can be rescheduled. This is particularly a problem when the trip missed is a late night trip. Despite careful review by office staff, problems can also appear when attempting to obtain farebox reports or when doing the distance calculations, as will be discussed later.

Data Analysis

Once each week CTA's data collectors turn in work completed the previous week. For each individual trip, staff must verify the assignment, determine revenue, determine distance, and complete the passenger-miles calculation.

Verification of Assignment

Verification of assignment is the first step in the post-data-collection-and-analysis process and is done in conjunction with the payroll process. A careful check must be made that the correct trip was worked and that the data collected are auditable and self-consistent. Stringent application of procedures developed within the department to handle issues involved in the data collection and verification process are an important part of maintaining the integrity of this process and ensuring that the required levels of precision and confidence are maintained.

When a data collector turns in the week's assignment sheets with work orders and data sheets attached, each work piece is examined to see that all pieces of information needed have been provided (i.e., driver or conductor badge number, car number, and actual times of trip start and finish); that the information on the data sheets indicates that the trip worked was at the proper time, between scheduled termini, and in the right direction; and that all information on the data sheet is self-consistent, that is, the data collector's addition is correct, that the number of passengers boarding and alighting match, and, in the case of bus trips, that the street names recorded are legible and clear.

Determination of Revenue

As mentioned before, to calculate overall unlinked trips using the revenue-based method, a GFI farebox report is needed for each successfully completed bus trip. This report must be ordered from the CTA's farebox computer. These farebox reports list the total revenue collected by fare category for each bus for an entire day. When a new driver boards the bus or a new run is initiated, a new line is generated by the farebox. At the start and end of each sample trip, the data collector asks the driver to enter the coded run number 999 into the bus farebox. This generates an individual line of data for that trip. Even when the driver fails to enter the complete 999 or replaces his driver badge number instead of his new run number, a new line is generated separating the information from this trip from all others completed by the vehicle that day. This information serves as a further check that the data collector actually boarded the vehicle.

Occasionally, there are problems with locating the proper farebox report for each vehicle among the daily reports generated for 2,247 buses operating out of 10 garages. Because farebox reports are organized by garage and dated by the day on which the fareboxes are probed at their home garage for the information recorded in them, several attempts are sometimes needed before the farebox report is found. Drivers, data collectors, and fareboxes all provide sources of error in this system. When a farebox report cannot be found, an otherwise complete and successful trip must be repeated.

Distance Calculation

Calculating distance for rail trips is easy and can be done simply by computer since the distance between rail stops is clearly known. However, the distance portion of the bus passenger-miles calculation is done manually using a scale and a good Rand McNally street map. This process is complicated by the fact that many of the routes served have several different variations.

When map work for the 1987 calculations began, it took a minimum of 2 hr per trip to complete each piece, that is, a maximum of four trips a day were being completed. By the end of the year, with the use of as much previous work as possible, the maximum number of trips that could be done in a day rose to eight.

More advantage could not be taken of route duplication because the pattern of stops used by passengers for a bus is different from one bus trip to another. Currently, a project is under way to simplify this process and accurately list the distance between all stops in all directions on all route variations on the system—a process so lengthy that it will probably be some time before useful data are available.

As with all other sections of the process, considerable supervisory time is spent making sure that all parts of the measurement process make sense, for example, that the total distance between stops matches the known route length. (Obtaining accurate route lengths was a time-consuming process in itself.)

Passenger-Miles Calculation

After map work is complete, passenger-miles traveled on each sample bus trip are determined. Rail calculations are easily performed using a Lotus 1-2-3 spreadsheet with accurate interstation distances stored. At CTA, each bus and rail sample trip is then entered into separate SAS data bases for calculating the overall average trip lengths and precision levels at 95 percent confidence for both the bus and the rail systems.

CONCLUSION

As is evident by now, many factors affect the ability of a large transit agency to collect Section 15 data. All things considered, meeting UMTA reporting requirements is quite expensive for CTA and for other large agencies. Data collected through this process are no doubt valuable to transit planners, but are they worth the expense incurred? Individualized modifications in the UMTA guidelines can facilitate the ability of large systems to gather the required reporting statistics more efficiently without sacrificing validity, still using manual observation of boardings and alightings.

Stratified sampling, for example, can prove more representative of overall system ridership especially for large 24 hr/day transit agencies. The concept of CTA's stratified rail plan is also transferable to the bus system and can better represent overall bus system ridership. Selecting a proportionate random sample in each stratum will reduce the variances normally seen in simply random samples. The size of the annual samples can, therefore, be reduced and still meet the current confidence and precision requirements.

Sampling each week also creates difficulty and unnecessary expense in gathering CTA ridership data. Annual CTA ridership typically varies less than 5 percent from year to year, although seasonal changes are observed. These seasonal changes, such as the absence of students in the summer, would still be represented in the sample if the sampling was performed on a monthly or quarterly basis. Quarterly sampling would allow a sampling blitz to occur in which trips are randomly selected and the data gathered in a 2 to 3 week period four times per year. With this method it may no longer be necessary to maintain a full staff of data collectors throughout the year especially if checkers or other operations personnel could be used.

Monthly samples would allow more efficient scheduling of sample trips even with the current staff of data collectors because the mandatory weekly sampling rule is removed. Either method permits more concentration of sample trips so that weekly staff time spent selecting random trips, scheduling their completion, and auditing and tabulating the results is slashed. Agency staff can then be allocated more efficiently. Every season of the year and every day of the week would still be represented in the sample and confidence and precision levels would go unchanged.

The requirement to randomize the day of the week on which sample trip data are collected is also an unnecessary expense for CTA and possibly other 24 hr/day systems. Statistical analyses have proven that day of the week is not a significant variable in determining average passenger trip lengths for weekday rail or bus samples. Eliminating this requirement further eases the burden of scheduling efficient data collection work pieces, and, because of randomness inherent in the process of assigning work-pieces, each weekday would still be represented in the annual sample.

Changes in technology can also ease the difficulty of collecting sample trip data. CTA is planning to install automatic passenger counters (APCs) on up to 25 percent of its bus fleet in the early 1990s. Not only will APCs facilitate transportation planning, but this technology can also be used for collecting Section 15 bus passenger-miles data. CTA has not yet sought UMTA approval for a method that relies on APC-equipped buses, but the potential for further efficiencies via this method looms on the horizon.

A better understanding of these and the other issues mentioned in this paper relative to the Section 15 data collection process at large agencies is important for transit officials. The requirement of collecting annual data is a necessary one, but more flexibility in UMTA regulations would be beneficial to all U.S. public transit systems—large and small. If individual agencies are allowed to adapt the basic UMTA requirements to fit the specialized needs of each system, valid data can still be gathered while permitting each transit authority to spend more valuable staff time analyzing the results of the actual ridership data collected. The transit service supplied can then better meet the transit service demand of urban areas all across the nation.

REFERENCES

1. *Sample Procedures for Obtaining Fixed Route Bus Operating Data Required Under the Section 15 Reporting System.* Circular C2710.4 UMTA, U.S. Department of Transportation, May 10, 1985.
2. *Distribution of Ridership by Hours.* CTA Operations Planning Department Report OP-X74263 Chicago, Ill., May 5, 1985.

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Parkrose Targeted Marketing Campaign Pass Incentive Program

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In September 1986, the Tri-County Metropolitan Transportation District of Oregon (Tri-Met) opened a light rail line through the northeast area of Portland to downtown. At the same time, several bus routes were altered to provide feeder service to the light rail. A direct-mail campaign offering a free 2-week pass was sent to 15,700 residents in the Parkrose neighborhood of Portland. The purpose of the packet was to increase ridership on the feeder bus routes by 10 to 20 percent. A mail-back survey to determine the effectiveness of the promotion was sent to persons who responded to the free-pass offer. Ridership counts were conducted before, during, and after the promotion to verify the promotion's actual impact. The study showed the following results: (a) The greatest response to the packet came from existing riders, with only 2.7 percent of all packets mailed resulting in a response from a nonrider; (b) ridership counts show that the promotion did not significantly increase ridership on feeder routes to the light rail line; however, ridership on light rail may have increased as a result of the promotion because survey results show that 92 percent of those who obtained a 2-week pass used it to ride light rail; (c) there is a higher proportion of senior citizens in the Parkrose area than in the rest of the transit district, so a campaign promoting shopping trips might have been more effective than one promoting commute trips to downtown Portland; and (d) a method for tracking new riders over several months needs to be developed to establish the attrition rate of new riders captured by the promotion.

The Tri-County Metropolitan Transportation District of Oregon (Tri-Met) operates within the boundaries of three contiguous counties in the northeast corner of the state. These counties are urban, suburban, and rural in nature. Until 1979, Tri-Met's service design policy was to provide no-transfer radial bus routes from surrounding and outlying areas to the downtown Portland core area.

In 1979 Tri-Met began a gradual expansion and reorientation of service in order to tap nondowntown market segments, as well as the downtown segments. Since then, Tri-Met has established and built upon a suburban timed-transfer focal-point system in the low-density areas of the region and an urban-grid system in the more highly developed east side and northwest areas of Portland.

As part of this new service design, in September of 1986, Tri-Met opened a new light rail line, the Metropolitan Area Express (MAX), to provide rapid transportation from the east side of Portland to the downtown area along the congested Banfield corridor.

The Tri-Met fare structure at the time the promotion was conducted was based on five geographic zones spreading out in roughly concentric circles from the downtown core area. The cash fare to travel in one or two zones was $0.85; to travel in three zones was $1.10. The cash fare to travel anywhere in the service district was $1.35. Travel within the downtown core area is free. Tri-Met passengers have three payment methods available to them: cash, discount tickets, or monthly passes. All fares are valid on both buses and MAX trains.

Tri-Met now carries more than 120,000 passengers each weekday throughout the system. This number accounts for 4 percent of all trips taken in the region each day and 43 percent of all rush-hour work trips to downtown Portland. Nearly one-quarter (24 percent) of the residents in the region use Tri-Met at least once per month.

DIRECT MAIL PROMOTION BACKGROUND AND METHODOLOGY

With the opening of MAX, several bus routes were altered to feed the light rail line. This new service, in addition to providing access to MAX for trips to downtown Portland, was intended to improve service to the nondowntown market on Portland's east side by creating more cross-town routes. Also, MAX's quick travel time offered an opportunity to increase patronage between east Multnomah County and the Central City area.

Although the bus route changes were instituted at the same time MAX opened, all promotional activities were centered around the MAX train. Initially, no efforts were made to inform area residents of the improved bus service. In January 1987 Tri-Met's marketing department began work on a direct-mail campaign to promote ridership on these cross-town MAX feeder lines in the Parkrose area of Portland. The campaign, directed at drive-alone commuters, offered a 2-week free pass to residents living in the target market area.

More than 15,700 informational packets were sent by carrier route to households in the target area. The packets contained an advertising piece advocating transit for commuters, a map of transit routes serving the area, a peak-hour schedule for MAX and the local feeder bus route, and a form to complete and redeem for a free "Special Pass" that was valid the last 2 weeks in April. The mailing containing the Special Pass

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was followed by a letter offering a May pass for half price when the recipient subscribed to the Pass-by-Mail program.

The following evaluation tools were used to help determine the success of the promotion:

- Ridership was measured on the feeder bus line before, during, and after the promotion to assess the actual effect of the promotion on ridership.
- The number of residents who requested a Special Pass in April and the number who purchased a discounted May pass by joining the Pass-by-Mail program were recorded.
- A follow-up survey with residents who requested the Special Pass was conducted. The purpose of the survey was to judge how effective the marketing strategy of using a pass incentive was in persuading commuters to use transit.

It was hoped that the promotion would increase ridership on the feeder bus lines by 10 to 20 percent. Specific targets for the level of response to the pass offers or the number of new riders captured were not developed. This paper discusses the results of the promotion in light of the evaluation tools.

RIDERSHIP COUNTS ON FEEDER BUSES

Before mailing the informational packets, the total number of boardings and alightings were counted on four cross-town feeder routes (Lines 22, 23, 24, and 71) where they connect with the MAX line. The purpose of these ridership counts was to provide a baseline against which to measure ridership during and immediately following the promotion.

Ridership counts on feeder bus routes were taken before the promotion began, the last 2 weeks of April (when the Special Pass was valid), at the beginning of May (passes offered at one-half price), at the end of May, and after the promotion ended. As Figure 1 shows, the promotion did not appear to have a significant impact on ridership.

Ridership counts on Line 71 are divided into northbound and southbound rides because the bus leaves the MAX station in both directions. For Lines 22, 23, and 24, the Gateway Station (where these lines connect with MAX) serves as the line terminus.

Ridership counts were not taken on MAX, so the actual impact of the promotion on MAX ridership cannot be measured. However, the follow-up survey indicates that most people who took advantage of the promotion rode MAX. These respondents usually chose transportation methods other than the bus to reach MAX, often driving. The stations where the feeder buses meet the MAX trains each have a park-and-ride lot.

RESPONSE TO PASS OFFERS

The direct-mail packets sent in March included an offer for a free Special Pass that would be valid the last 2 weeks in

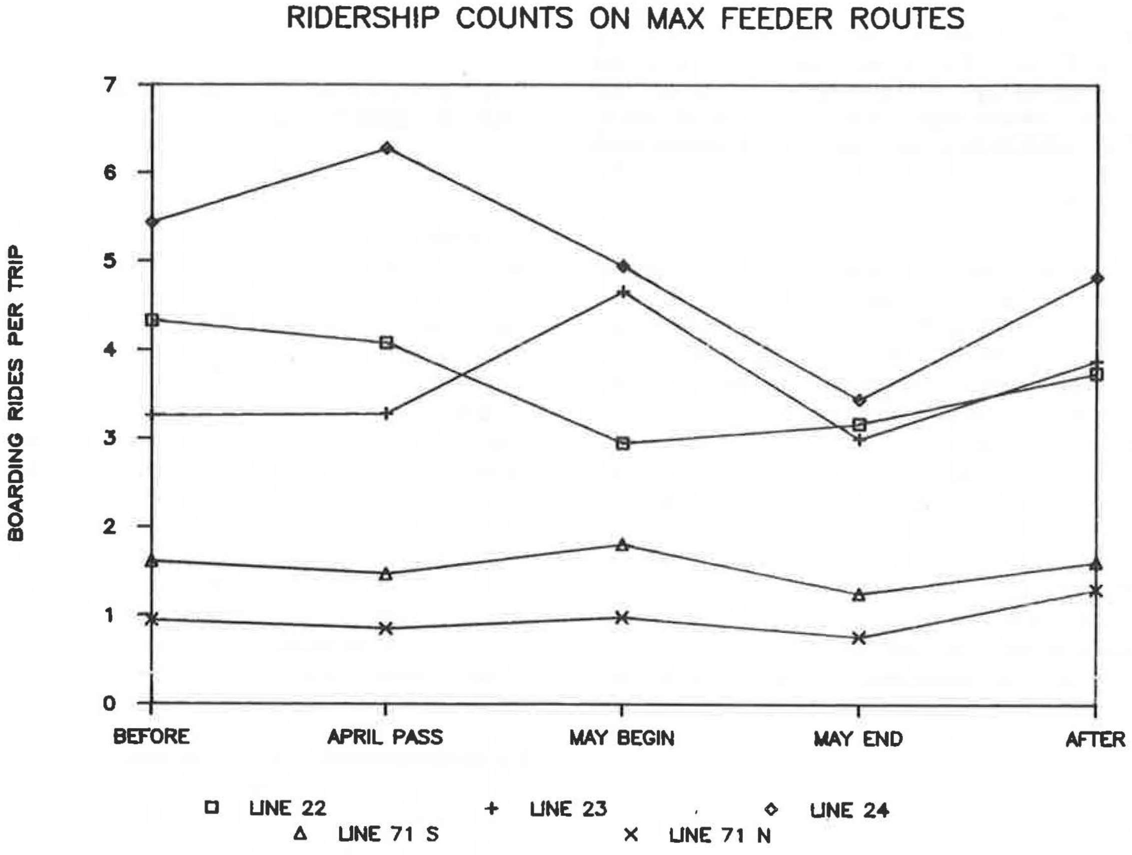

FIGURE 1 Ridership counts on MAX feeder routes.

April, in addition to several informational pieces about bus routes, peak-hour schedules, and how the buses connect with MAX to go downtown. To obtain the pass, a respondent simply had to check a box and write his or her name on a postage-paid response card. Only one Special Pass was offered per household.

More than 4,300 households responded to the offer for a Special Pass—a 27 percent response rate. The passes were mailed on April 13, 1987, with a letter that affirmed the respondents' decision to try Tri-Met, instructed respondents in how to use the pass, and directed them to centers where they could get more information if needed.

A second letter was sent to those who requested the Special Pass offering respondents a 50 percent discount on a May pass if they joined the Pass-by-Mail program. The Pass by Mail program allows respondents to purchase a pass through the mail. Passes must be paid for by the tenth of the month preceding the month for which the pass is valid. Payment can be made by check or automatically charged to a major credit card. A flyer containing a description of the Pass-by-Mail program and an order form was included in this mailing. A total of 528 persons took advantage of the discount offer for a May pass and joined Pass-by-Mail, representing 12 percent of the persons who requested the Special Pass for April.

A computerized method for tracking respondents who joined Pass-by-Mail as a result of the promotion was not established. A hand tally showed that only 153 of the respondents who joined Pass-by-Mail purchased a pass or tickets in June. This number suggests that 71 percent of the persons who joined Pass-by-Mail did so only to take advantage of the May pass discount and did not intend to continue in the program.

SURVEY RESULTS

Methodology

A mail-back questionnaire was sent to the 4,315 persons who requested the April Special Pass. Tri-Met received 1,028 completed questionnaires—a response rate of 24 percent.

Virtually all respondents who joined the Pass-by-Mail program also completed a questionnaire, representing 51 percent of the survey sample. Empirical data from actual Pass-by-Mail applications showed that only 12 percent of the target population joined Pass-by-Mail. Therefore, a weighting factor has been employed to expand and more closely align survey results with characteristics found in the targeted survey population of 4,315.

After correcting for response bias, a sample of this size has a maximum margin of error of ±3 percent at the 95 percent confidence level. That is, if the survey were replicated 100 times, in 95 cases the results would not differ from the original study by more than 3 percent.

Packet Contents

Virtually all (95 percent) of the survey respondents found the information packet to be helpful, including 65 percent who said it was very helpful. When asked what additional information they would have liked to have included, 29 percent said more information was unnecessary, 15 percent requested schedule information for other than peak hours, 7 percent asked for fare information, and 6 percent asked for maps or route information. Nearly 1 respondent in 10 (9 percent) said he or she already knew the system.

Use of Special Pass

Three-quarters of the survey respondents used the Special Pass personally, 2 percent gave the pass to someone else, and 23 percent did not use the pass, even though they requested it from Tri-Met. Respondents who did not use the pass personally said they were too busy to use the pass (44 percent) or that using a car was easier (11 percent). One-third of respondents cited other reasons for not using the pass, such as illness or being out of town.

This finding differs from results of other surveys that show that the most often mentioned reason for not using a pass is that a car is easier or more convenient. One reason for this difference may be because respondents had to actively request a pass from Tri-Met rather than simply receive a free pass in the mail. This required action on the part of Parkrose area residents may have served to reduce the number of respondents who were likely to use a car despite receiving a free pass.

Of the survey respondents who used the pass personally, 90 percent were Tri-Met riders before the promotion began, including 37 percent who regularly commuted to work on Tri-Met. Figure 2 displays the type of trips made using the Special Pass by everyone who used it—new riders and persons who were riders before the promotion.

A surprising finding was that work trips ranked third among trip purposes, behind recreation. The high percentage of recreation trips may reflect persons taking advantage of the pass to "joy ride" on the new light rail line. When MAX opened, Tri-Met ridership increased dramatically as people flocked to try the train. Given that the promotion was designed to encourage residents to ride MAX by providing information about how to reach the light rail, it seems likely that respondents used the information and the free pass to take an experimental ride on the train.

In fact, almost all (92 percent) of the respondents who used the pass personally took at least one trip on MAX. However, most found ways other than the bus to reach the light rail. Overall, only 20 percent reached MAX by bus. Of the remainder, 43 percent drove to a park-and-ride lot at a MAX station, 26 percent walked, 6 percent were dropped off by car, and 4 percent mentioned other means of transportation. Persons who were riders before the promotion were more likely to ride the bus or walk to the MAX station than new riders. In terms of travel mode used by Special Pass holders, more than one-third (37 percent) rode the bus and MAX either separately or in combination, 9 percent rode the bus only, and 54 percent rode MAX only.

Although ridership counts show that the promotion did not significantly increase ridership on the feeder routes during the promotional period, survey results indicate it succeeded in convincing 30 percent of the new riders to try the bus (2 percent bus only, 28 percent bus and MAX combination). Ridership counts on MAX during the promotional period are not available.

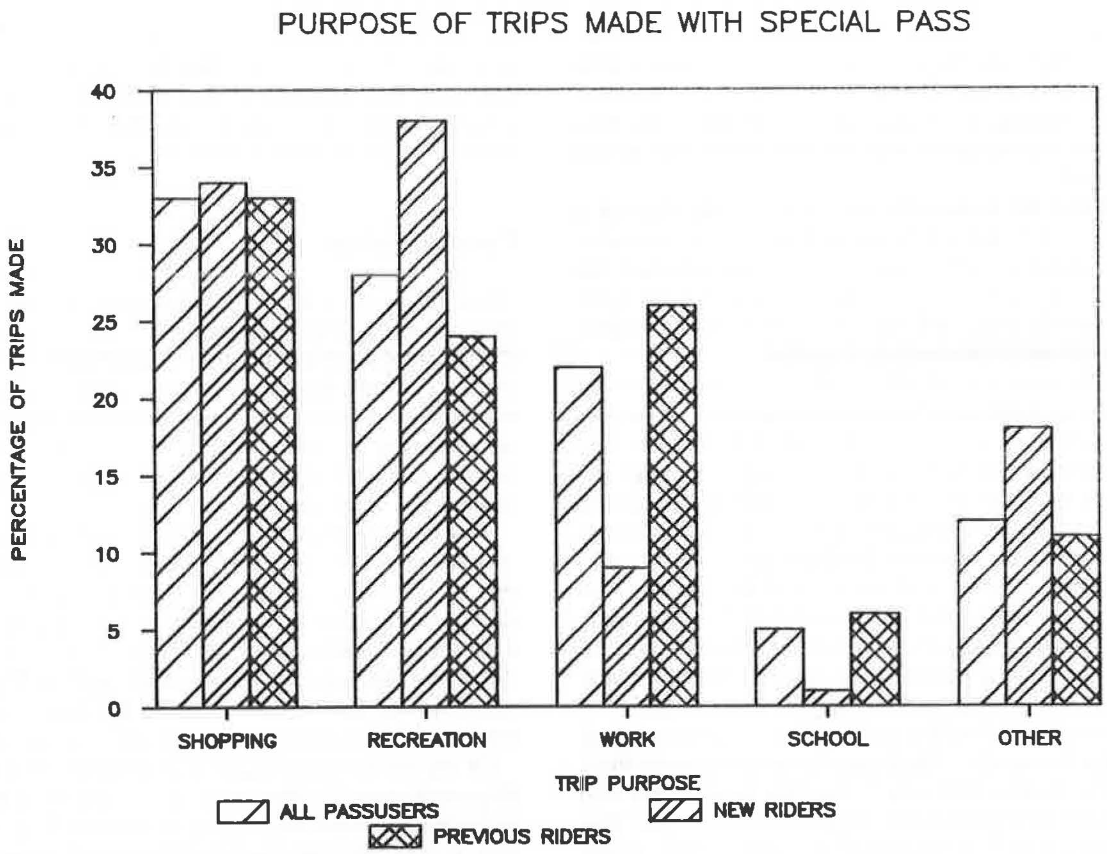

FIGURE 2 Purpose of trips made with special pass.

May Pass Offer

Only 11 percent of the survey respondents took advantage of the half price offer for a May pass through the Pass-by-Mail program. Of these respondents, 2 percent were new Tri-Met riders. The remaining 9 percent rode Tri-Met before the promotion.

It appears that the Pass-by-Mail program had a very low retention rate of persons who joined in response to the promotion. As mentioned earlier, a hand tally in June indicated that 71 percent of those who joined Pass-by-Mail dropped out immediately after obtaining the discounted pass.

Survey results corroborate this finding. Before the promotion, 21 percent of the respondents who purchased a May pass were monthly pass users, 33 percent used discount tickets, and 42 percent paid with cash. When asked how they planned to pay their fare in June, respondents who paid cash before the promotion reverted to their earlier behavior. Overall, 41 percent of the May pass users said they would pay with cash in June, 31 percent would use a pass, and 28 percent planned to buy discount tickets.

Even persons who used passes before the promotion, purchased a pass in May, and intended to purchase a pass in June were reluctant to remain in the Pass-by-Mail program. It may be that these individuals compute from month to month whether they will benefit from purchasing a pass. Another reason might be that respondents are resistant to the prepayment plan inherent in the Pass-by-Mail program and want to control when, or if, they make such a payment.

Prepromotion Ridership Characteristics

Nearly half (48 percent) of the survey population do not commute to work, 8 percent commute between 1 and 3 days per week, and 44 percent commute 4 or more days per week. It is not known how many of these respondents work in downtown Portland.

Before the promotion, 31 percent of the survey respondents who commute travelled to work on Tri-Met, 53 percent drove alone, and 10 percent drove or rode with others. The percentage of survey respondents who commute on Tri-Met is much higher than the percentage of transit commuters among the overall population of Parkrose. A 1986 study conducted by Tri-Met showed that in the general Parkrose population, 77 percent of commuters drove alone, 15 percent drove or rode with others, and 4 percent commuted on transit.

As might be expected, persons who rode Tri-Met before the promotion are more likely to commute on transit than persons who were nonriders. Cash was the most popular method of paying fares regardless of whether one regularly commutes on Tri-Met. More than half (60 percent) of the survey respondents reported paying their fare with cash before the promotion, 26 percent used tickets, and 9 percent used a monthly pass. Although this percentage of pass users is lower than average for the region (average is 22 percent), it is comparable with pass usage among Parkrose residents.

The use of tickets and passes was more prevalent on MAX than on buses alone or for trips involving a combination of bus and MAX. Forty-three percent (43 percent) of respondents who commute on MAX reported paying their fares with discount tickets. By comparison, 23 percent who rode the bus and 29 percent who rode both the bus and MAX paid their fares with discount tickets.

One reason for this difference in payment methods could be because ticket machines are located at all MAX stations. Passengers are required to have a valid proof of payment (transfer, ticket, or pass) before boarding the train. The machines sell tickets in books of 10 at a discounted rate or individually at the regular cash price. Some respondents may have confused the single ticket with the discounted ticket, thus overreporting the number of "discount tickets" used on MAX. Another possibility is that the increased convenience and availability of discount tickets encourages ticket use on MAX.

Propensity for Continued Ridership

Virtually all respondents (99 percent) planned to make two or more trips on Tri-Met in June. Riding frequency increased substantially when comparing the number of trips respondents planned to make in June with the number of trips they made in the month before the promotion. This comparison is shown in Figure 3.

Not surprisingly, two-thirds (66 percent) of the respondents who said they would definitely ride in June were Tri-Met riders before the promotion began. The remaining 34 percent were new riders enticed by the promotion to try Tri-Met.

When asked how they intended to pay their fares in June, more than half of all survey respondents said they planned to purchase a pass, 27 percent planned to buy discount tickets, and 16 percent said they would pay cash. This projected behavior represents a major shift from how respondents paid their fares before the promotion. Before the promotion, 60 percent paid cash, 26 percent used discount tickets, and 9 percent used a monthly pass.

While the convenience of a pass is a great advantage, it seems unlikely that survey respondents actually purchased the number of passes or tickets projected in the survey results. As shown in Figure 3, 72 percent of the survey respondents plan fewer than 29 trips in June. With the exception of honored citizens, respondents making fewer than 29 trips each month would actually pay more per ride using a pass than if they paid with cash. Among respondents who planned more than 29 transit trips, 20 percent said they would purchase a pass, 36 percent said they would use discount tickets, and 44 percent intended to pay cash.

Survey research experience has shown that intended behavior is rarely matched in actuality. Even though respondents

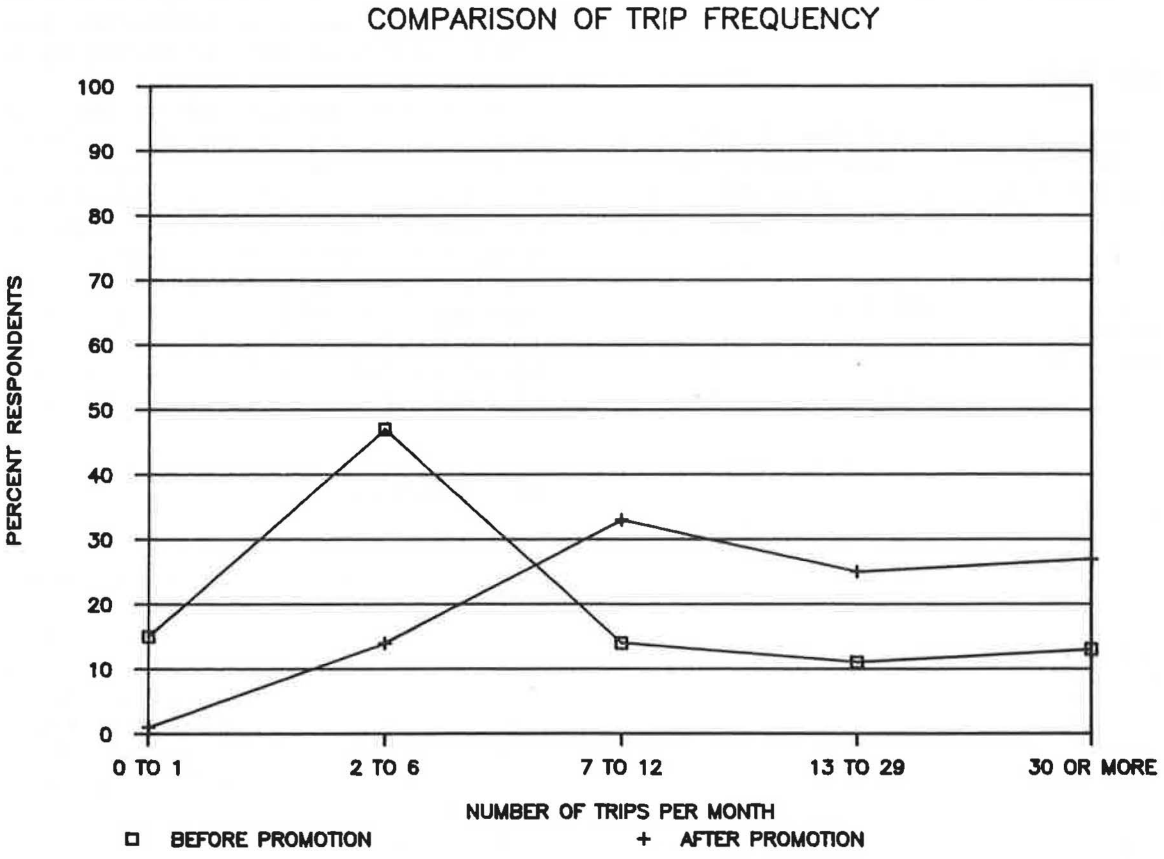

FIGURE 3 Comparison of trip frequency.

intend to ride more often or purchase a monthly pass, many may not follow through for one reason or another. As noted earlier, most respondents were not sufficiently committed to purchasing a June pass to remain in the Pass-by-Mail program.

Satisfaction with Tri-Met Service

Respondents are pleased with the service Tri-Met provides whether or not they ride. More than half (57 percent) of the survey respondents said they were very satisfied with the service Tri-Met provides. An additional 31 percent said they were somewhat satisfied.

While the proportion of new riders who expressed satisfaction with Tri-Met's service is comparable to the number of respondents who rode Tri-Met before the promotion, opinions of new riders tended to be more positive. Two-thirds of the new riders said they were very satisfied with the agency's service and 18 percent said they were somewhat satisfied. Among the established riders, 56 percent said they were very satisfied with Tri-Met service and 35 percent said they were somewhat satisfied.

When asked why they were satisfied or dissatisfied with Tri-Met's service, over half the reasons mentioned were positive, including 33 percent praising MAX. The reasons most often mentioned were that MAX is reliable, frequent, and fast. Only 7 percent of all comments dealt with negative aspects of MAX including 5 percent who were displeased with the heating and air conditioning. No other reasons garnered more than 3 percent of the total comments made.

Demographic Profile

The demographic characteristics of survey respondents, in comparison with those of the general Parkrose population, are shown in Table 1. The age distribution among respondents who did not ride Tri-Met before the promotion, but took advantage of the Special Pass, differs from that of the total survey population. In general, there were more persons aged 55 to 64 who responded to the promotion (30 percent of the new riders were in this category) and more persons who were ages 35 to 44. Slightly more new riders were female and income levels were similar to those of the overall survey population.

TABLE 1 COMPARISON OF DEMOGRAPHIC CHARACTERISTICS

Characteristics	Survey Respondents (%)	1986 Parkrose Population (%)
Age		
Under 24	10	20
25 to 34	17	17
35 to 44	17	18
45 to 54	13	14
55 to 64	24	11
65 and older	19	20
Income		
Less than $15,000	27	28
$15,000 to $24,999	27	31
$25,000 to $34,999	21	24
$35,000 to $49,999	15	10
$50,000 or more	10	7
Gender		
Male	31	48
Female	69	52
Rider status before promotion		
Non-rider	15	89
Rider	85	11

DISCUSSION OF RESULTS

To evaluate the overall success of the promotion, results were measured against three criteria:

- Did the promotion increase ridership on feeder lines to MAX?
- Did the promotion help capture new transit riders?
- Did the promotion influence existing Tri-Met riders to ride more often?

Ridership on Feeder Routes

Ridership counts and survey results indicate the promotion had limited success in attracting more riders to the feeder routes. According to the survey, 2 percent more respondents rode the bus to MAX using their Special Pass than rode the bus to MAX before the promotion. Because the survey did not ask which bus respondents rode, it is not possible to ascertain if respondents who made trips by bus only rode a feeder bus or another bus in the system. It is possible the number of respondents who rode feeder buses is higher than 2 percent if respondents who made bus-only trips were to be included.

Of the nonriders who requested a free pass (10 percent of the total sample), 31 percent rode either the bus alone, or a combination of bus and MAX, during the promotional period. In addition, as a result of the campaign, 5 percent of the persons who rode only MAX before the promotion tried riding the bus to or from the light rail station.

Survey results show the promotion was very successful in attracting riders to MAX. Overall, 92 percent of the survey respondents who used the pass personally took at least one trip on MAX. However, rather than riding a feeder bus, most found alternate means of reaching the light rail.

New Riders Captured

Overall, only 2.7 percent of all packets mailed evoked a response from a nonrider. The remainder were from persons who rode Tri-Met before the promotion. One reason for this response bias may be that, as in mail-back surveys, respondents self-select. That is to say, persons with a particular interest in the product or service being promoted are more likely to respond than persons who are not predisposed toward the product or service. In this case, persons who already used Tri-Met were more likely to request a Special Pass than persons who did not use Tri-Met.

Overall, 48 percent of those who were nonriders before the promotion were enticed to try transit. A high percentage of these respondents intended to keep riding. Eighteen percent said they would definitely ride in June, whereas 33 percent said they would probably ride in June.

Increased Riding Frequency

The final question dealt with whether the promotion encouraged persons who rode Tri-Met before April to ride more often. Survey results show a potential overall increase in riding frequency on the part of respondents who rode Tri-Met before the promotion began. Before the promotion, only 44 percent of survey respondents who were transit riders made trips on the bus or MAX more than six times per month. According to survey results, the promotion has increased the intention of respondents to ride. Eighty-six percent of these respondents planned at least 7 trips in June, including 29 percent who planned 30 or more trips.

Although the promotion appears to have had a positive impact on riding frequency among respondents who rode Tri-Met before the promotion, these results must be viewed with caution. Historically, market research shows that actual behavior changes occur less frequently than intended, hence the impact may not be as strong as survey results indicate.

CONCLUSIONS AND RECOMMENDATIONS

Direct-Mail Packet Was Well Received

Survey results show the packet itself was well received and considered very useful by those who responded to the promotion. It appears the packet contents were not a major reason for the low number of riders attracted.

Recommendation. Include similar information in direct-mail packets for future promotions of this type.

Promotion Design Produced High-Level Response From Existing Tri-Met Riders

Ninety percent of the responses to the initial mailing came from Tri-Met riders. The direct-mail promotion was good for Tri-Met's public image, rewarding passengers with 2 weeks of free rides and a discounted May pass, thus reaffirming their decision to ride.

Although survey results are not definitive, it seems unlikely that the increased riding frequency among existing riders was sufficient to offset revenue losses from the free or reduced passes. This supposition is reinforced by the survey results indicating how few respondents were enticed to join and continue membership in the Pass-by-Mail program.

Recommendations.

- Ask respondents to indicate on the response card in the direct-mail packet the number of transit trips they make per month.
- Send a book of discount tickets to existing riders (thus preserving the public image benefit) and a 2-week pass with the offer of a discounted pass the following month to nonriders.

New Riders Were Good Prospects for Conversion to Transit

Only 10 percent of all responses to the promotion were from nonriders. Although this is a fairly low response for nonriders, those who did respond demonstrated significant interest in converting to transit. Nearly half (48 percent) of the nonriders who responded to the direct-mail packet used their Special Pass to make at least one trip on transit. Having nonriders actively request passes narrows the target market so follow-up offers are concentrated in the market segment with the highest potential.

Recommendation. Send discount tickets and passes, as described previously.

Promotion Objectives Were Not Specific Enough To Facilitate Good Research

The stated objective of increasing ridership on feeder routes by 10 to 20 percent was difficult to measure. Moreover, it was the only stated objective. Although ridership counts are indicative of the promotion's effectiveness, concrete conclusion cannot be drawn from this information alone. Ridership increases could have resulted from any number of factors including the promotion.

A more clearly defined overall objective or specific, measurable subobjectives would aid greatly in designing and analyzing the promotion. For example, was the promotion supposed to entice nonriders to use feeder buses and MAX, or simply to increase overall system ridership?

Even if a marketing promotion fails to meet its overall objective, it may achieve other secondary goals. For instance, although this promotion seems to have had a limited effect on increasing feeder route ridership or attracting new riders, there is some indication that it may have boosted MAX ridership.

The design of the packet materials was inconsistent with the stated overall objective of increasing ridership on feeder routes. Rather than promoting all types of trips, the packet materials were specifically designed to promote work trips.

Recommendations.

- Clearly delineate all major and subobjectives at the beginning of a promotion.
- Develop promotional materials and research design to facilitate measuring the success of the promotion in meeting its stated objectives.

Characteristics and Needs of Target Market Were Not Defined

The promotional materials were designed for Parkrose area residents who commute to work in downtown Portland. It is unclear from the stated objective whether the target audience was all Parkrose area residents, all commuters from that area to downtown, or only commuters to downtown who did not ride Tri-Met.

In any case, materials in the direct-mail packet did not take into account the demographic characteristics of the Parkrose area. Demographic data show that a high proportion of area residents are over age 65 and are, therefore, unlikely to be commuters. Within Parkrose, 20 percent of the residents are over age 65 compared with 12 percent in the entire Tri-Met district.

Survey results showed that even though the promotion was designed to promote work trips to downtown, only 9 percent of the new riders used the pass for work purposes. Shopping and recreational trips were more prevalent. One reason for this finding (in addition to demographics) may be that new riders are unsure how to use transit and are unwilling to risk being late to work on a trial run. Shopping and recreation trips are often more leisurely, so there is less risk in trying transit. Another reason for the low number of commute trips may be that transit has already captured most of its commuter market potential.

Recommendations.

- Identify target market and research demographic characteristics.
- Design promotion with needs of target market in mind. For example, in this promotion, materials emphasizing nonwork trips, such as shopping or recreation, may have been more successful at attracting new riders.

Questionnaire Design Could be Improved

Although it yielded a lot of useful information, the survey could have been more effective if designed more carefully. Similar questions concerning ridership frequency and trip purpose need to be directly comparable. For example, respondents were asked at the beginning of the survey how many trips they had made in the last *month* and then asked how many trips per *week* they planned to make in June.

A second example is that respondents were asked how they usually got to work. Later they were asked how many trips they had taken on Tri-Met during the promotion. Respondents who rode MAX were asked how they reached the light rail station. Because respondents were not asked how they reached MAX before the promotion and were not asked about nonwork trips before the promotion, it was not possible to use the survey to quantify increases in riding frequency on the MAX.

Finally, although the promotion materials were geared specifically for respondents who were making work trips to downtown, the survey did not ascertain how many respondents actually make this type of trip.

Clearly stated subobjectives and a detailed description of the target market will help alleviate these problems.

Recommendations.

- Design the survey to accurately measure specific objectives set out at the beginning of the promotion.
- Pay close attention when wording questions to ensure that results will be directly comparable.

Effective Method for Tracking New Riders is Needed

A method for tracking riders captured as a result of the promotion needs to be developed to ascertain how long they remain transit users and with what frequency. This information would aid in determining the cost-effectiveness of a given promotion over time. Some tracking could occur in the Pass-by-Mail program. However, tracking only Pass-by-Mail members would be insufficient.

Although many persons joined the Pass-by-Mail program, most dropped out in the following month. This may be due in part because ridership behavior varies from month to month and respondents calculate each month whether purchasing a pass would be cost-effective. In addition, it may be unrealistic to expect new riders to go from zero trips to more than 29 trips per month on a regular basis.

Recommendations.

- Place a flag in the Pass-by-Mail computer file to identify persons who joined in response to a particular promotion and then track them throughout the subsequent months.
- Conduct research 4 to 6 months after the promotion to determine whether new riders continued to ride transit and if not, why not.

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