Limited-Stop Bus Operations: An Evaluation

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ABSTRACT

Limited-stop bus services have the capability of serving a ridership demand market between that of regional express and that of local bus operations. Limited-stop bus services in New York City's borough of Manhattan were evaluated by comparing performance characteristics and passenger use to those of local service on the same routes. Random spot-survey results and recent secondary data sources revealed considerable travel time savings, faster average operating speeds, rider preference for limited buses (where available), and attraction levels comparable to those of local bus service. Modest operating cost savings were computed, with stopping frequencies closer to express service being the most economical. Among the types of service-related cost savings cited from employing limited scheduling, annual savings from peak vehicle reductions amount to more than 60 percent of total possible economies expected through using limited bus runs for roughly half the peak period trips on suitable routes. Two sets of bivariate regression models were computed and calibrated to serve as general sketch-planning guides for reviewing routes that may benefit from limited-service implementation. Five warrants explaining what service revisions and performance modifications are essential if limited bus operations are to be feasibly used to cut costs and attract ridership are presented.

With the cooperation and assistance of the New York City Transit Authority and Polytechnic Institute of New York, a data-collection effort was conducted to make a rudimentary, and where feasible a statistically valid, comparison (by route composites) of local and limited bus operating characteristics.

Data derived from random spot surveys included passenger counts and delay durations, frequencies, and causes of stopped time. Previous studies of operating speeds, travel times, peak-period costs, and passenger use were applied to adjust survey results and estimate the impact of a modified or faster limited service (1,2). From these data, a comparative microeconomic (using component cost figures) and macroeconomic analysis using monetary and time costs per route determined the significance of savings and service enhancements expected from peak-period limited bus scheduling.

Because of the greater time savings possible in Manhattan, operating cost estimates were based on the most conservative cost savings, which are generally applicable to cities with lower population and commercial space densities.

DEFINING LIMITED SERVICE

To a lesser extent than are express operations, limited service is designed to serve passenger-stops only at major sites and along major corridors and trip-generation zones. Figure 1 shows how various degrees of limited service can be scheduled.

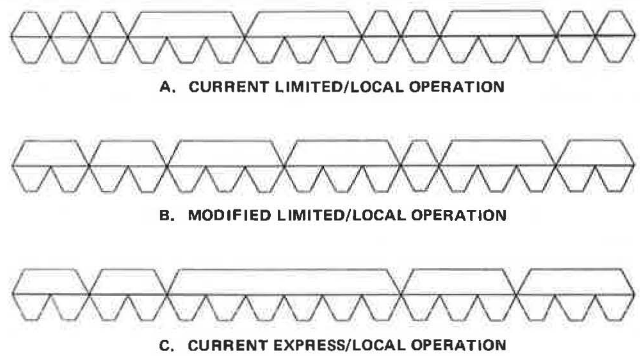

FIGURE 1 Examples of passenger-stop operating strategies.

Using a method of illustrating stopping frequencies applied by Vuchic et al. (3), each horizontal diagram in Figure 1 compares a specific type of bus operation (shown above a one-way route line) to a local bus stopping frequency (shown below each line). Each diagram illustrates a single trip, and each connection point along these diagrams is roughly equivalent to five scheduled and four actual passenger-stops per route segment. Therefore, local-stop, current limited, and modified limited trips represent approximately 75, 50, and 30 scheduled passenger-stops and 60, 40, and 25 actual average passenger-stops per trip.

The top diagram of Figure 1 depicts current limited operations--those peak-period services now in existence on five routes (M-1, 4, 5, 10, and 32) in the borough of Manhattan (4). Because current limiteds make an extensive number of stops in designated route segments, their greater pick-up coverage results in operating characteristics closer to those of local bus scheduling.

The middle diagram shows a modified version of limited service that was recently initiated on one route (M-15) serving the east side of the borough. Further reductions in pick-up coverage permit modified limiteds to approach levels of performance associated with express operations.

Comparative stopping frequencies of express and local service are shown in the bottom diagram. Although express schedules provide higher levels of service and ridership attraction potential, their suburban orientation, longer route distance, and far greater route spacing prohibit their meeting an overwhelming share of nonlocal intracity travel demand.

STUDY FINDINGS

Operating Speeds and Travel Times

A significant increase in surface transit operating speeds causes shorter travel times and reductions in the number of peak vehicles needed, which result in a decrease in annual operating costs and capital spending. An increase in operating speeds can also retain or generate greater ridership per capita for the bus system (5).

On-board surveys revealed the crucial influence of mixed traffic conditions on limited-bus speeds. Observations of route segment performance variations indicated a tendency for limited buses to be from 50 to 100 percent faster than local buses under light traffic and urban highway conditions and 20 to 30 percent faster under moderate traffic and arterial roadway conditions. Both speeds begin to approach parity under heavy traffic and central business district (CBD) conditions.

Figure 2 shows a microanalysis that uses the mean travel times and headways from 15 north-south routes selected for evaluation on the basis of the analytical determination of minimum route distances greater than 5.0 miles to maintain acceptable travel time savings per typical user trip length. This microanalysis shows an average increase in operating speeds of approximately 0.9 mph (6.4 to 7.3 mph) and 1.6 mph (6.4 to 8.0 mph) for current and modified limited bus service, respectively. Higher speeds resulting from stopped time reductions occurred because of declines in passenger-stop frequencies and, to a lesser extent, all other delay causes (6).

A relationship between travel times and route distances was established by calculating the percentage change in trip times from Figure 2 to plot travel times for local, limited, and modified service. Data from the 15 Manhattan bus routes studied were used, and Figure 3 shows a set of linear regression configurations with a correlation of $r = 0.89$. For each type of stop service, three bivariate regressions were computed for predicting trip times by route lengths. After a steady rise in travel time savings, a point of diminishing returns may be

Average Travel Time of Local Service $= \frac{60(8.9 \text{ miles})}{6.4 \text{ mph}} =$ 83.4 minutes

Est. % of Passenger Stop Delay Time			
Local	=	58 Stops x 14 secs.	= 13.5 minutes
CLS	=	36 Stops x 15 secs.	= 9.0 minutes
MLS	=	24 Stops x 16 secs.	= 6.4 minutes

Current Limited Delay Time $= \frac{(13.5)\ 36}{58} = 8.38$ mins. Mod. Limited Delay Time $= \frac{(13.5)\ 24}{56} = 5.59$ mins.

13.5 mins.-8.38 mins.=5.13 mins. 13.5 mins.-5.59 mins.=7.91 mins.

Est. % of Signal Stop Delay Time			
Local	=	30 Stops x 25 secs.	= 12.5 minutes
CLS	=	22 Stops x 26 secs.	= 9.5 minutes
MLS	=	16 Stops x 27 secs.	= 7.2 minutes

Current Limited Delay Time $= \frac{(12.5)\ 22}{30} = 9.17$ mins. Mod. Limited Delay Time $= \frac{(12.5)\ 16}{30} = 6.67$ mins.

12.5 mins.-9.17 mins.=3.33 mins. 12.5 mins-6.67 mins=5.83 mins.

Est. % of Remaining Stop Delay Time			
Local	=	11 Stops x 20 secs.	= 3.7 minutes
CLS	=	6 Stops x 22 secs.	= 2.2 minutes
MLS	=	3 Stops x 24 secs.	= 1.2 minutes

Current Limited Delay Time $= \frac{(3.7)\ 6}{11} = 2.02$ mins. Mod. Limited Delay Time $= \frac{(3.7)\ 3}{11} = 1.01$ mins.

3.7 mins-2.02 mins.=1.7 mins 3.7 mins.-1.01 mins.=2.7 mins.

CURRENT AND MODIFIED LIMITED TIME SAVINGS

	Trip Time	PSD	TSD	OTD		New Trip Time
Current	83.4	- 5.12	+ 3.33	+ 1.7	=	73.2 minutes
Limited		(83.4 - 10.2)				(10.2 mins. Saved/Trip)
Modified	83.4	- 7.91	+ 5.83	+ 2.7	=	67.0 minutes
Limited		(83.4 - 16.4)				(16.4 mins. Saved/Trip)

Current Limited Travel Speed & Time Savings $= \frac{60(8.9 \text{ miles})}{73.2 \text{ mins.}} = 7.3$ mph

New Run Time

(20.4 mins. Saved/Run)

Modified Limited Travel Speed & Time Savings $= \frac{60(8.9 \text{ miles})}{67.0 \text{ mins.}} = 8.0$ mph

(32.8 mins. Saved/Run)

FIGURE 2 Speed and delay changes resulting from current 36-stop and modified 24-stop limited bus operation.

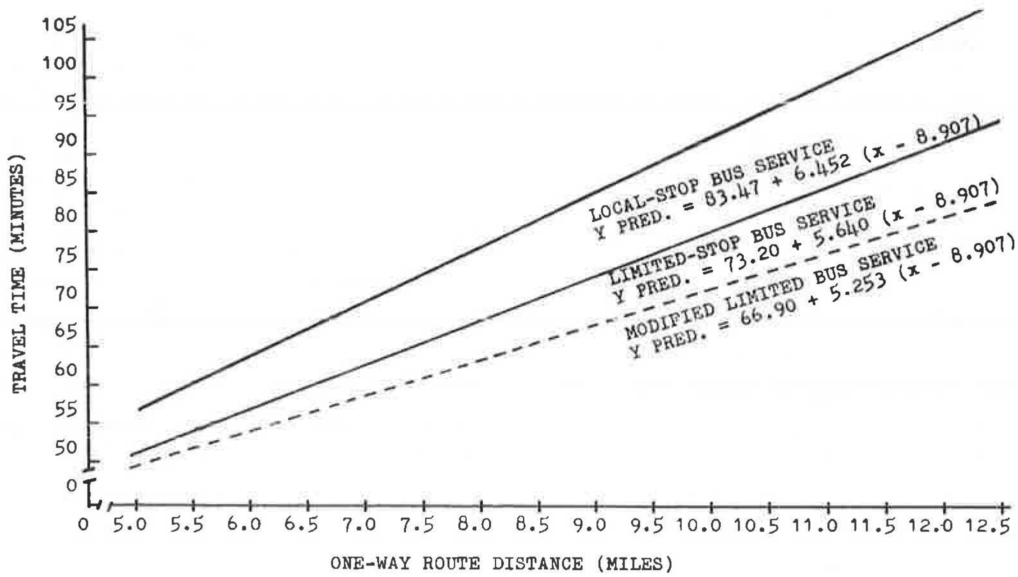

FIGURE 3 Relationship between peak travel times and route distances.

reached for route lengths longer than 9 miles; however, actual time savings are greatest for the longest routes.

Service Costs and Savings

An economic comparison of bus service cost components was conducted to estimate total capital and operating costs, the relative share of total costs each represents, and the amount of savings possible from both current and modified limited bus operations.

With headways, miles traveled, and existing scheduling held constant, a detailed microeconomic analysis of every cost component (labor, capital, maintenance, fuel, and so forth) permitted the calculation of total annual operating costs at roughly $7.35, $6.68 with $0.67 savings, and $6.39 with $0.96 savings per mile for local, current limited, and modified bus operations, respectively (6).

Although labor costs represent 60 percent of peak operating expenses, more than 64 percent of total annual savings would result from lower peak vehicle requirements. Reducing the number of buses needed to maintain present schedules would cause the greatest proportion of cost savings obtainable through limited bus scheduling. Travel times computed previously for limited operations were divided by existing average peak headways to calculate declines in peak vehicles by route as shown in Figure 4. Decreases in fleet size ranged from 2 to 11 buses per route depending on stop service, route length, and headways (7).

Comparing adjusted limited and modified peak travel times to annual operating costs (computed by multiplying cost per bus-mile by total bus-miles) resulted in a set of bivariate equations applicable for predicting cost savings directly from decreases in peak travel times. With a correlation of r = 0.89, regression lines plotted in Figure 5 represent a linear relationship with plots that shift to the left for each degree of travel time reduction caused by limited or modified service scheduling. Checks made to compare the validity of predicted cost values with those obtained through microeconomic analysis were found to have a 95 percent fit between both cost derivations.

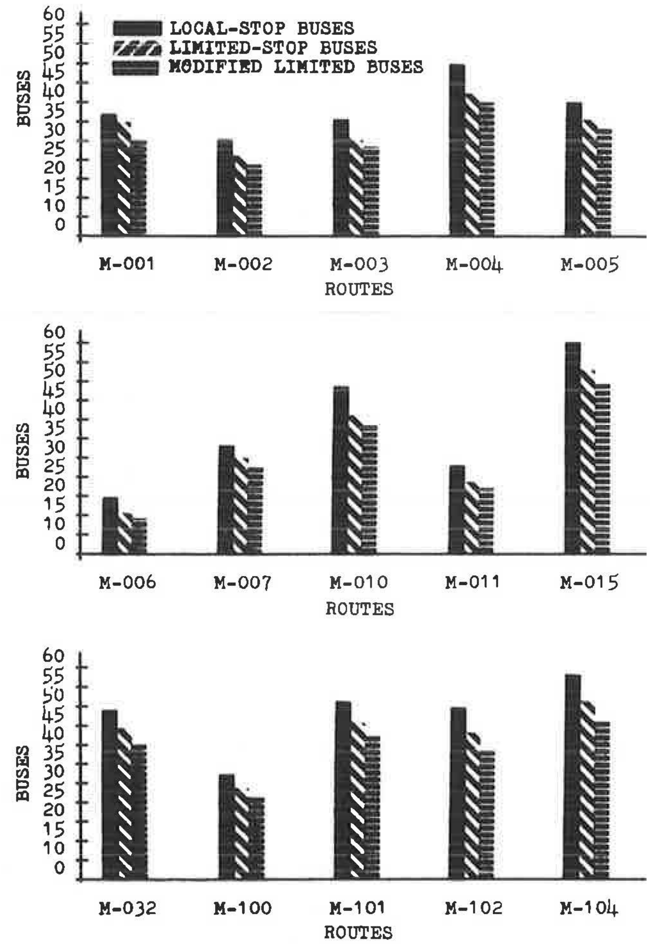

FIGURE 4 Peak vehicles by route and service type.

Table 1 applies regression equations derived from Figure 5 to estimate the total annual operating costs and savings predicted by route and stop service. Savings per route computed in Table 1 revealed modest declines of 9 to 10 percent in oper-

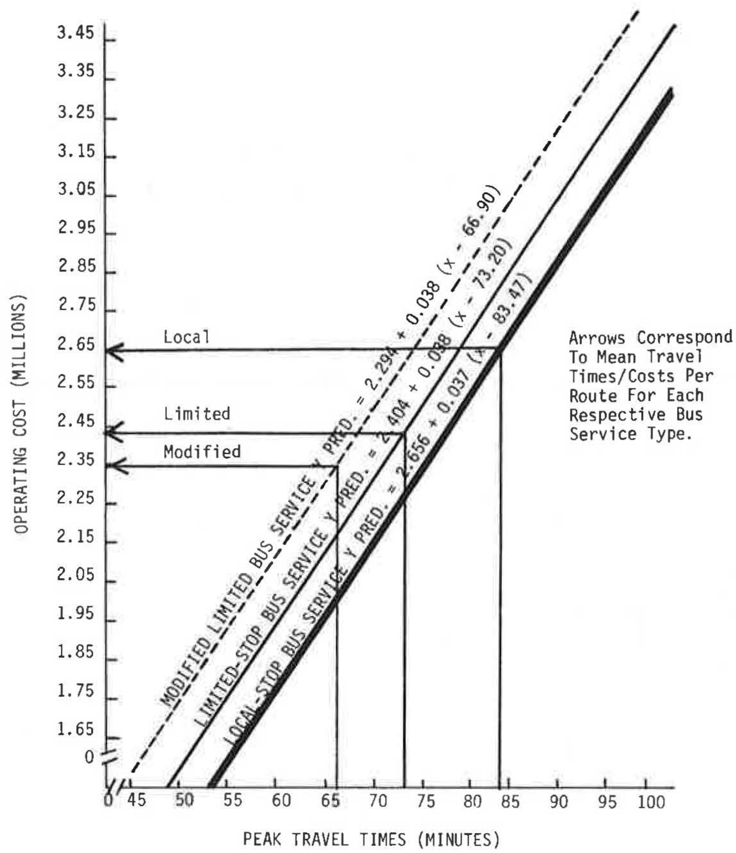

FIGURE 5 Relationship between peak operating cost and travel times.

ating costs for current limited service and marginally greater economies of from 13 to 14 percent for modified limited operations.

Present annual savings of more than $1.7 million are estimated for existing current limiteds on five routes and recently implemented modified limiteds on Route M-15. If modified limited service ran on all 15 routes with the minimum length necessary for noticeable user travel time savings, nearly $5.5 million would be saved annually. Although these savings are quite modest for major metropolitan bus systems, potential revenues from the retention of or

TABLE 1 Summary of Annual Total Costs per Route per Peak 6 Hours

ROUTE NUMBER	ROUTE NAME	LOCAL COSTS (MIL.)	LIMITED COSTS (MIL.)	MODIFIED COSTS (MIL.)	LIMITED SAVINGS (MIL.)	MODIFIED SAVINGS (MIL.)	PRESENT SAVINGS (MIL.)
M-001	5th+MAD. AV.	3.10	2.80	2.66	0.30	0.44	0.30
M-002	5th+MAD. AV.	2.80	2.53	2.42	0.27	0.38	----
M-003	5th+MAD. AV.	3.07	2.80	2.66	0.27	0.41	----
M-004	5th+MAD. AV.	2.76	2.48	2.39	0.28	0.37	0.28
M-005	5th+MAD. AV.	3.22	2.91	2.77	0.31	0.45	0.31
M-006	7th/AV. OF AM.	1.76	1.59	1.53	0.17	0.23	----
M-007	7th/AV. OF AM.	2.32	2.09	2.00	0.23	0.32	----
M-010	7th+8th AV.	2.69	2.45	2.30	0.24	0.39	0.24
M-011	9th+10th AV.	2.32	2.09	2.00	0.23	0.32	----
M-015	1st+2nd AV.	2.91	2.64	2.50	0.27	0.41	0.41 [a]
M-032	5th+MAD. AV.	2.32	2.09	2.00	0.23	0.32	0.23
M-100	AMSTERDAM AV.	2.54	2.29	2.19	0.25	0.35	----
M-101	3rd+LEX. AV.	3.44	3.10	2.96	0.34	0.48	----
M-102	3rd+LEX. AV.	3.14	2.83	2.69	0.31	0.45	----
M-104	BROADWAY	1.67	1.52	1.50	0.15	0.17	----
SYSTEMWIDE TOTALS =		40.06	36.21	34.57	3.85	5.49	1.77

[a]Since January 1982, modified limited buses have been operating on route M-15.

increase in discretionary (noncaptive) ridership may produce greater economies in the future.

Passenger Use and Preferences

The level of use and ridership preference for existing limited bus service were established by recording load profiles, interviewing CBD-bound riders, and counting passenger boardings during the simultaneous (bunched) arrival of both service types (8).

The load profile shown in Figure 6 is typical of routes using peak limited service and indicates similar ridership attraction for local and limited buses, a peaking of on-board occupancies just below the fringe of the CBD, and a tendency for limited buses to experience heavier boarding volumes near the outer terminals of CBD-oriented bus routes. Although no definitive findings can be inferred from the small percentage of trips surveyed, the use profiles obtained represent an affirmative indication that limited service (where provided) is being used to a significant degree.

A bus-stop questionnaire registered ridership preferences at high-volume locations for three routes with limited service. Questionnaire findings revealed that 50 to 60 percent of peak riders prefer using limiteds where they are available. This preference rate is supported by actual boarding counts taken to verify interview response rates. Only 12 percent of the responding limited bus riders walked beyond their nearest bus stop. Thus, a longer distance and a locally based demand market does exist in subregions between the range of local and express buses.

Observations made during the simultaneous arrival of local and limited buses indicated that from 42 to 74 percent of total boardings were made on buses providing limited operation. These findings support the results just described from on-board load profile and ridership questionnaire surveys.

Although modified limited service was not surveyed, secondary sources and data examining express-type operations point to significantly higher levels of passenger use (9,10).

RECOMMENDATIONS AND CONCLUSIONS

To evaluate routes for limited-service applications, five warrants to be considered before proposing practical limited-stop scheduling were developed from the findings reviewed in this paper:

1. Determine if a minimum user travel time savings of 6 min per trip or 12 min per day for limited

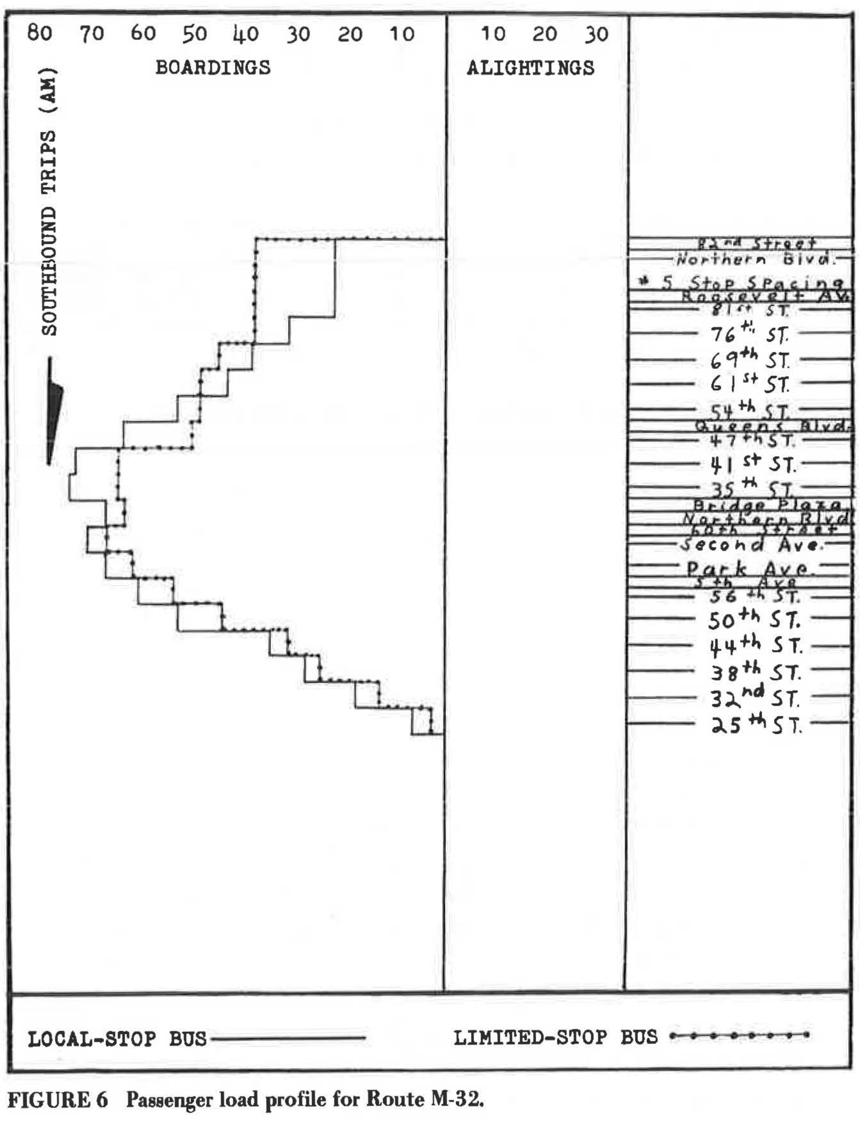

FIGURE 6 Passenger load profile for Route M-32.

bus passengers is feasible. User travel time reductions of more than 5 min per trip are usually necessary before time savings become perceivable to the riding public or significant enough to justify maintaining separate limited operations.

2. Analyze the ability to raise average operating speeds a minimum of 1 to 2 mph for limited bus trips if existing or revised route configurations, and stop frequency/walking distance to stop tradeoffs permit. In lower density cities, and where transportation system management (TSM) enhancements are included, increases in speeds from 3 mph over local buses are attainable.

3. Study the potential use of peak-period limited bus service by reviewing trip origin-destination and distribution counts per route section or zone. Relatively inexpensive surveys (as part of regular monitoring efforts) using questionnaires and boarding-alighting counts for routes meeting warrants 1 and 2 could be conducted to supplement existing data.

4. Estimate the impact of reducing peak vehicle requirements on routes where increases in on-board load factors (caused by a loss in seats per hour) could be alleviated by targeting peak-period users more efficiently between local and limited trips. The number of buses assigned as limiteds can be approximated by the percentage of longer distance trips expected per selected route.

5. Establish which stopping strategies for limited buses maximize ridership and access coverage. Stopping frequency configurations may include the following: (a) nodal or widely spaced distributions of bus stops at major activity points, (b) clustered or segmented patterns concentrating stops in residential and commercial catchment areas, and (c) combined nodal and clustered patterns that alternate stop frequencies by route segment to meet unique corridor trip distributions.

Schedules that permit riders to plan their arrivals, and the importance of comfort and convenience factors to express riders, may also apply to intraurban limited-stop bus users if significant quantitative and qualitative service improvements can be realized (10).

Difficulties in funding transit and the elimination of federal operating subsidies require an examination of differential fare policies for lowering operating deficits and earning surplus revenues from more affluent markets in order to maintain basic local service for all bus transit users.

Use of a package of low-cost TSM measures with limited operations could potentially double time and cost savings. Such measures can include reserved bus lanes, signal-timing optimization, route modifications, higher capacity vehicles, automatic monitoring techniques, and targeting marketing efforts.

The most essential differences between local and limited-stop bus operations have been summarized. Two sets of bivariate linear regression equations to facilitate the selection of routes for limited service by forecasting time and cost savings have been computed, and a list of five warrants derived from research findings to direct study or analysis projects has been provided.

Increases in operating speeds and travel time reductions resulting from the introduction of limited-stop bus service could produce substantial cuts in peak-period user travel times and total annual operating costs per bus-mile. Added savings from a faster type of modified limited service would largely result from its greater potential to attract additional ridership.

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