

Downtown Space for Buses— The Manhattan Experience

HERBERT S. LEVINSON, LAWRENCE LENNON, AND JERRY CHENG

The limit of acceptable express bus service in Manhattan is defined. Where additional buses might be accommodated is shown on the basis of system capabilities and passengers' destinations. At present, there is little space for additional express buses during peak hours in the Manhattan central business district in Madison, Fifth, and Sixth avenues in Midtown and along Broadway and Church Street in Lower Manhattan. Volume-capacity analyses indicate that setting limits on the number of express buses is not practical at present, because bus volumes entering the Manhattan hub during peak hours have declined.

The express buses that serve New York City and surrounding areas in Westchester, Nassau, and Suffolk counties receive and discharge their passengers on streets and avenues in the Manhattan central business district (CBD). Buses serving New Jersey via the Holland Tunnel also have on-street collection and distribution. The Port Authority Midtown bus terminal provides off-street loading and unloading for most New Jersey buses.

Most express buses in Midtown concentrate along Madison, Fifth, and Sixth avenues in the heart of the office district. Similarly, express buses in Lower Manhattan concentrate on the only two continuous streets—Broadway and Church Street.

Concern about the effects of express buses on Manhattan streets has grown during the past decade. Many questions have been raised about the desirability and practicality of adding more express buses on Midtown and downtown Manhattan streets, including the following: Can more express buses be accommodated on Manhattan CBD streets? Should limits be imposed on the number of express buses entering Manhattan by sector or just on specific streets? What street management changes are necessary to better serve existing express buses or accommodate additional buses? Is it practical to increase express bus volumes on crosstown streets or peripheral avenues? Can capacity for additional express buses be provided by reducing the number of local buses on key avenues?

This paper addresses these concerns and questions. The limits of acceptable bus service in the Manhattan CBD are defined. Local and express bus flows as they relate to the Manhattan street system are analyzed, bus volumes and capacities are compared, and changes in bus operations and street traffic management to improve service and permit increased bus flows are identified. Where additional buses might be accommodated is shown on the basis of street system capabilities and passengers' destinations.

H. S. Levinson, Herbert S. Levinson Transportation Consultant, 40 Hemlock Road, New Haven, Conn. 06515. L. Lennon and J. Cheng, New York City Department of City Planning, 22 Reade Street, Room 6N, New York, N.Y. 10007.

ANALYSIS STEPS

The analysis included the following steps.

1. Travel characteristics of express and local bus passengers were reviewed to assess the practicality of rerouting service.
2. Trends in the number of buses and bus passengers entering the Manhattan CBD were analyzed to identify the magnitude and nature of past and probable future changes.
3. The number of peak-hour buses crossing key east-west screen lines in Midtown and Lower Manhattan was estimated. These flows provided a basis for volume-capacity analyses.
4. Capacities were estimated on a street-by-street basis to define limits of acceptable bus service.
5. These limits were compared with peak-hour bus volumes to see where additional buses might be accommodated.
6. The additional buses that could be accommodated by expanding the bus lane system, rerouting buses, or building a bus terminal were estimated.
7. The additional buses from Steps 5 and 6 were added to the peak bus flows on the CBD cordon, from which possible cordon limits were identified.
8. Finally, the policy implications of adding buses and ways to improve the use of downtown bus space were identified.

TRAVEL PATTERNS AND ATTITUDES

The travel patterns and attitudes of New York City express and local bus riders were obtained from surveys conducted by the New York City Department of City Planning (NYC DCP) during mid-1989. Approximately 1,900 express passengers were surveyed on their trip into Manhattan, and approximately 1,300 local bus riders were interviewed as they boarded buses on Midtown avenues at or near 50th Street. The survey results are summarized as follows.

Local Bus Passengers

Approximately half of all local bus passengers surveyed were on work trips, 16 percent were on shopping trips, and 15 percent were on business trips. More than 80 percent were able to use the subway for their trip. The reasons cited for not using the subway were (a) subway is less convenient, 43 percent; (b) buses are safer, 30 percent; and (c) buses are more comfortable, 27 percent.

The short travel distances of most local bus passengers—median distances of 20 to 26 blocks, or 1.00 to 1.25 mi—

reflect the convenience afforded by the local bus service. Such trips are not easily transferable to subway lines because of the time lost walking to and from and entering and leaving subway stations.

Thus, there appears to be much less duplication of local bus-subway service than a review of transit route maps might suggest. Each mode has its own market and catchment area, and neither is a substitute for the other.

Express Bus Passengers

Most express bus passengers (63 percent) traveled 5 min or less to their destination. Once they left the bus in Manhattan, 93 percent walked to their destination, and 7 percent used other means. If the express bus service were not available, 80 percent would use subways or suburban rail lines, 12 percent would come by car, and 8 percent would use vans. Most express bus passengers were former subway or railroad riders. About 54 percent of the express bus passengers cited convenience as the main reason for using express buses. Next in order of importance were safety, 21 percent; comfort, 13 percent; and speed, 7 percent.

Destinations of the express bus passengers surveyed are mapped in Figure 1. About 67 percent reported destinations in Midtown Manhattan. Another 19 percent reported Lower

Manhattan destinations; 11 percent reported destinations in the Valley; and 3 percent reported destinations north of 63rd Street. Thus, Midtown Manhattan appears to be the main focus of express bus passengers.

More than 8 out of every 10 express bus riders with Midtown destinations were traveling to places located between Third and Eighth avenues. The other two riders were going to places east of Third Avenue or west of Eighth Avenue. The destinations of Midtown passengers were distributed as shown in the table below.

Destination	Percentage
Third to Fifth avenues	49.7
Fifth to Eighth avenues	31.8
East of Third Avenue	17.0
West of Eighth Avenue	1.5
Total	100.0

Thus, the present concentration of express bus routes on Madison, Fifth, and Sixth avenues reflects the large concentration of passengers' destinations along these blocks. Placing express buses on avenues that are peripheral to the Midtown office core is not practical because most of these avenues are too far from where people want to go.

The Midtown area located between Third and Eighth avenues accounted for 42 percent of all workers' destinations in 1980 compared with 55 percent of all reported express bus passengers' destinations in 1989.

VOLUMES AND PATTERNS OF EXPRESS BUSES IN MANHATTAN

Cordon and screen-line counts of local and express buses in Midtown and Lower Manhattan conducted by the New York Metropolitan Transportation Council and the New York City Department of Transportation (NYCDOT) were analyzed to determine the magnitudes and patterns of local and express bus flow, identify trends in express volumes on Manhattan streets, and assess the impacts on each Manhattan avenue.

Daily Bus Volumes Entering Manhattan Hub

The patterns of express and local bus passengers and vehicles entering the Manhattan hub (i.e., Manhattan south to 60th Street) on a business day in the fall are given in Table 1. The number of daily express bus passengers entering the hub grew steadily from 134,563 passengers in 1977 to a peak of 206,364 passengers in 1984, an increase of 53 percent. However, during the period 1984 to 1988, express bus ridership decreased by 16.8 percent, to 171,819 daily riders.

The number of express riders coming from New Jersey increased steadily between 1977 and 1988, from about 85,200 to 122,600. In contrast, the number of express bus riders coming from the Bronx, Brooklyn, Queens, and Westchester peaked in 1984 and has dropped steadily since.

The maximum number of express buses entered the Manhattan hub in 1986—some 7,751 buses. Of this total, 68 percent came from west of the Hudson River, 30 percent from New York City, and 2 percent from Westchester. In 1988, 7,174 buses entered the hub, a 7.4 percent decline from 1984.

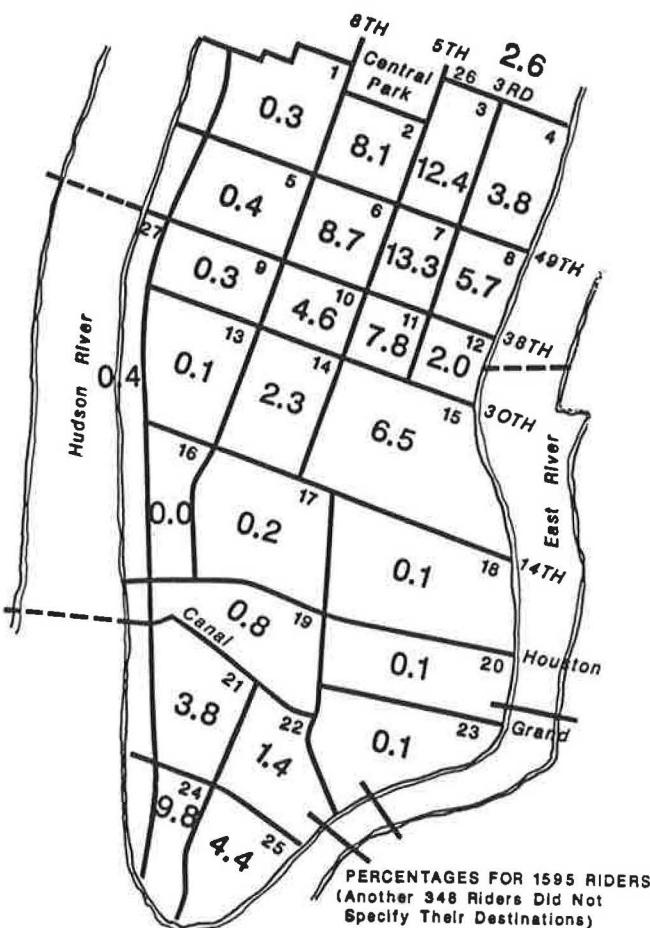


FIGURE 1 Destinations of express bus passengers, 1989.

TABLE 1 EXPRESS AND LOCAL BUS PASSENGERS AND VEHICLES ENTERING THE HUB ON A FALL BUSINESS DAY

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Bus Passengers												
Express Bus												
New York City	46,859	52,519	51,139	60,361	62,505	62,102	62,473	79,472	67,448	61,834	53,404	47,088
West of Hudson	85,194	83,618	85,490	89,879	90,094	108,129	114,217	123,673	131,100	127,299	121,550	122,600
North of NYC	2,510	2,580	2,610	2,682	2,596	3,021	3,063	3,219	2,672	2,342	2,132	2,131
Total	134,563	138,717	139,239	152,922	155,195	173,252	179,753	206,364	201,220	191,475	177,086	171,819
Local Bus												
	98,297	89,697	92,210	100,321	88,472	101,718	101,217	86,131	96,127	75,556	72,278	70,513
Total Passengers	232,860	228,414	231,449	253,243	243,667	274,970	280,970	292,495	297,347	267,031	249,364	242,332
Bus Vehicles												
Express Bus												
New York City	1,591	1,360	1,315	1,665	1,526	1,602	1,802	2,440	2,217	2,357	2,002	1,846
West of Hudson	3,535	3,546	3,564	3,663	3,232	3,639	4,199	4,639	5,140	5,286	5,069	5,219
North of NYC	108	106	109	115	126	127	129	124	125	108	115	109
Total	5,234	5,012	4,988	5,443	4,884	5,368	6,130	7,203	7,482	7,751	7,186	7,174
Local Bus												
	3,435	3,259	3,168	3,316	3,114	3,395	3,336	2,701	3,192	3,535	3,084	3,304
Total Buses	8,669	8,271	8,156	8,759	7,998	8,763	9,466	9,904	10,674	11,286	10,270	10,478

Source: Hub-Bound Travel 1988, New York Metropolitan Transportation Council

Total Peak-Hour Bus Volumes Entering and Leaving the Hub

Almost 1,770 buses entered the hub during the 8 to 9 a.m. morning peak hour in 1985, compared with 1,630 in 1987 and 1,480 in 1988. The number of buses leaving the hub during the 5 to 6 p.m. afternoon peak hour reached a maximum of almost 1,530 in 1985 and then dropped to 1,410 in 1987 and 1,370 in 1988.

Similar trends were noted for express bus volumes into and out of the hub. The number of inbound buses reached a maximum of about 1,510 in 1985, declining to almost 1,400 in 1987 and 1,225 in 1988. The afternoon peak outbound bus volume dropped from 1,310 in 1985 to about 1,190 in 1987 and 1,160 in 1988.

The largest declines occurred across the 60th Street cordon. They reflect population and demographic changes, subway service improvements, new subway cars, and growing traffic congestion.

Peak-Hour Buses Crossing Selected Screen Lines

The critical capacity "crunch" for buses on Manhattan streets and avenues is within the CBD at points of major passenger

boarding and alighting. This is because the ability of curb lanes to handle passengers and buses at key boarding points determines the capacity of the system. Accordingly, analyses were made of bus flows across the 60th Street, 44th Street-50th Street, and Maiden Lane-Liberty Street screen lines during the two peak hours.

60th Street Screen Line

The distributions of express and local buses by avenue across the 60th Street screen line are given in Tables 2 and 3 for the 1987 morning and evening peak hours, respectively. The concentrations of inbound buses along Madison Avenue are apparent. Fifth Avenue carried 78 percent of the total inbound express buses, and Madison Avenue carried 79 percent of the total outbound express buses.

44th Street-50th Street

Tables 4 and 5 give the number of peak-hour local and express buses on each Manhattan avenue across the 44th Street-50th Street screen line (for conditions between 1986 and 1988). These tables indicate a major concentration of express buses

TABLE 2 EXPRESS AND LOCAL BUS VOLUME CROSSING 60TH STREET SCREEN LINES BY FACILITY, 8 TO 9 A.M. PEAK HOUR, INBOUND, 1987

60TH STREET SECTOR	EXPRESS BUS	LOCAL BUS	TOTAL
FDR DRIVE	3	0	3
YORK AVENUE	10	16	26
2ND AVENUE	0	29	29
LEXINGTON AVENUE	14	32	46
FIFTH AVENUE	87	59	146
BROADWAY	6	54	60
COLUMBUS AVENUE	2	17	19
WEST END	0	8	8
TOTAL	122	215	337

TABLE 3 EXPRESS AND LOCAL BUS VOLUME CROSSING
60TH STREET SCREEN LINES, 5 TO 6 P.M. PEAK HOUR,
OUTBOUND, 1987

60TH STREET SECTOR	EXPRESS BUS	LOCAL BUS	TOTAL
FDR DRIVE	2	0	2
YORK AVENUE	0	11	11
1ST AVENUE	8	32	40
3RD AVENUE	10	29	39
MADISON AVENUE	97	41	138
8TH AVENUE	8	11	19
BROADWAY	0	53	53
AMSTERDAM AVENUE	6	8	14
WEST END AVENUE	0	7	7
TOTAL	131	192	323

SOURCE: Hub-bound Travel
New York Metropolitan
Transportation Council

TABLE 4 PEAK-HOUR BUSES BY TYPE OF BUS, 44TH
STREET-50TH STREET SCREEN LINE, 8 TO 9 A.M., 1986-1988

	EXPRESS	LOCAL	TOTAL
LOCATION (SB)			
2ND AVENUE	89	46	135 (78)
LEXINGTON AVENUE	38	21	59
5TH AVENUE	104	60	164
7TH AVENUE	11	52	63
BROADWAY	13	23	36
9TH AVENUE	-	7(1)	7
TOTAL	255	209	464 (78)
LOCATION (NB)			
1ST AVENUE	-	50(1)	50
3RD AVENUE	54	21	75 (11)
MADISON AVENUE	135	45	180
AVE OF THE AMERICAS	118	24	142
8TH AVENUE	-	50(1)	50
10TH AVENUE (1)	-	7	7
TOTAL	297	147	504 (11)

() DEADHEADING BUSES

SOURCE: NYCDOT - UNFRANCHISED BUS PLANNING STUDY, MARCH, 1988

(1) NYCTA 1988 LOCAL BUS VOLUMES

on Madison Avenue, Fifth Avenue, and Avenue of the Americas.

During the morning peak hour, there were 255 express and 209 local buses southbound and 297 express and 147 local buses northbound. Fifth Avenue carried 41 percent of the southbound express buses and 29 percent of the southbound local buses. Madison Avenue carried 45 percent of the northbound express buses but only 31 percent of the northbound local buses. Avenue of the Americas carried 40 percent of the northbound express buses.

During the evening peak hour, there were 161 express and 178 local buses southbound and 229 express and 216 local buses northbound. Fifth Avenue carried 85 percent of the southbound express buses but only 33 percent of the north-

bound local buses. Madison Avenue carried 59 percent of the northbound express buses but only 23 percent of the southbound local buses. Avenue of the Americas carried 34 percent of the northbound express buses but only 12 percent of the local buses.

Maiden Lane-Liberty Street

Table 6 gives the number of peak-hour buses crossing the Maiden Lane-Liberty Street screen line during the morning peak hour. The southbound express buses concentrated on Broadway, and the northbound express buses concentrated on Trinity Place/Church Street. FDR Drive, however, carried some southbound express buses.

TABLE 5 PEAK-HOUR BUSES BY TYPE OF BUS, 44TH STREET-50TH STREET SCREEN LINE, 5 TO 6 P.M., 1987-1989

	EXPRESS	LOCAL	TOTAL
<u>LOCATION (SB)</u>			
2ND AVENUE	4	20	24
LEXINGTON AVENUE	14(a)	44	58
5TH AVENUE	137	59	196
7TH AVENUE	-	13	13
BROADWAY	6(a)	36	43
9TH AVENUE	-	6	6
TOTAL	168	178	339
<u>LOCATION (NB)</u>			
1ST AVENUE	-	40	40
3RD AVENUE	10(a)	44	54
MADISON AVENUE	134	49	183
AVE OF THE AMERICAS	77	25	102
8TH AVENUE	8(a)	52	60
10TH AVENUE	-	6	6
TOTAL	229	216	445

NOTES & SOURCES

- (a) - 1987 - NORTHBOUND ACROSS 60TH STREET CORDON
 LOCAL BUSES - NYCTA 1988 SCHEDULES
 EXPRESS BUSES - 1989 FIELD SURVEYS NYC DCP

TABLE 6 PEAK-HOUR BUSES CROSSING MAIDEN LANE-LIBERTY STREET SCREEN LINE BY TYPE OF BUS, 8 TO 9 A.M., 1986-1988

LOCATION	EXPRESS	LOCAL	TOTAL
<u>SOUTHBOUND</u>			
FDR DRIVE	37 (23)	0	37 (23)
SOUTH STREET	1	0	1
WATER STREET	36	7	43
BROADWAY	96 (13)	13	109 (13)
WEST STREET	57 (39)	1	58 (39)
TOTAL	227 (75)	21	248 (75)
<u>NORTHBOUND</u>			
FDR DRIVE	53	0	53
WATER STREET	11	7	18
TRINITY PLACE/ CHURCH STREET	143	21	164
WEST STREET	0	72	72
TOTAL	207	100	307

() DEADHEAD BUSES

SOURCE: UNFRANCHISED BUS PLANNING STUDY
 NYCDOT, MARCH, 1988

ANALYSIS OF CONGESTED CORRIDORS

Several bus corridors in Manhattan are critical in terms of bus volumes and speeds, including Fifth, Sixth, and Madison avenues in Midtown and Broadway and Church Street in Lower Manhattan. Each of these streets carries more than 100 buses in the peak hour, each is heavily used by express buses, and each has peak-hour bus speeds of less than 8 mph (usually 3 to 5 mph).

The maximum observed hourly bus volumes crossing selected screen lines in the congested corridors are summarized

in Table 7. These flows are based primarily on the bus volume counts conducted during the past decade at the various cordon and screen lines. They show the highest volumes that were observed without regard to the year of observation.

- At the 60th Street screen line, a maximum volume of 223 buses was observed southbound on Fifth Avenue during the morning peak hour. During the evening peak hour, Madison Avenue carried a maximum volume of 206 buses northbound.

- At the 44th Street-50th Street screen line, a maximum volume of 196 southbound buses was observed on Fifth Av-

TABLE 7 MAXIMUM OBSERVED PEAK-HOUR BUS VOLUMES

SCREEN LINE AND AVENUE DIRECTION	NUMBER OF BUSES	
	AM PEAK HOUR	PM PEAK HOUR
A. 60TH STREET		
FIFTH AVENUE SOUTHBOUND	146(223)	NA
MADISON AVENUE NORTHBOUND	NA	138(206)
B. 44TH/50TH STREET		
FIFTH AVENUE SOUTHBOUND	164	196
MADISON AVENUE NORTHBOUND	180	183
AVENUE OF THE AMERICAS NORTHBOUND	142	102
C. MAIDEN LANE/LIBERTY STREET		
BROADWAY SOUTHBOUND	109	150
TRINITY PLACE/CHURCH STREET NORTHBOUND	164	NA

Note: 1987-9 Volumes are shown. Maximum volumes between 1983 and 1989 are shown in parenthesis

NA - Not Applicable

enue, 183 northbound buses on Madison Avenue, and 142 northbound buses on Avenue of the Americas.

DEFINING LIMITS OF ACCEPTABLE BUS SERVICE

The next step was to estimate (a) how many additional peak-hour buses Manhattan CBD streets can accommodate and (b) how many additional buses can cross the Manhattan cordon when keyed to the ability of the Manhattan streets to accommodate them.

Capacity Factors

The maximum number of buses that can operate through a street system is determined by the capacity of the approach roadways and that of the points of maximum passenger boarding and discharge, whichever is less. In most cases, capacity is limited by the ability of buses to board and alight passengers at the busiest bus stops. This is true in the Manhattan CBD. Many crossings of the East and Hudson rivers can accommodate more buses (though cars would be displaced); the choke points for buses occur along a few arteries in Midtown and Lower Manhattan.

The maximum number of buses that can operate on any street depends on the characteristics of the street (e.g., number of travel lanes, traffic signal timing, traffic regulations, and availability of bus-only lanes), the nature of adjacent land use (e.g., residential or commercial); the patterns of passenger boarding and alighting, and the fare collection methods used.

More specifically, the capacity of a bus lane in buses per hour depends on the following:

- Green/cycle ratio,
- Dwell times at major stops,
- Specified spacing (in seconds) between buses,

- Number of effective berths, and
- Allowance for bunching of vehicles and overloading or failure of the stop.

Dwell times depend on the door configuration, fare structure, and number of boarding and alighting passengers.

The availability of bus priority lanes significantly increases the number of buses that a street can accommodate. Curb space and the availability of bus-only lanes are far more important determinants of street capacity than is street width. Ideally, the number of buses operating on any street should be less than the maximum number possible.

The 1985 *Highway Capacity Manual* (1, Table 12-11) suggests the following guidelines for the maximum number of buses per lane per hour. The guidelines are based on the assumption that buses operate in an exclusive lane and stop to discharge or receive passengers.

Level of Service	Arterial Street	CBD Street
D	81-105	61-80
E (maximum)	106-135	81-100

Suggested Guidelines

Suggested guidelines for acceptable bus service on Manhattan streets were developed on the basis of observations of bus operations and volume and speed data. The guidelines, given in Table 8, adapt the *Highway Capacity Manual* criteria to Manhattan. The values set forth in the manual were modified to reflect Manhattan operating conditions and experiences. Table 8 shows both the maximum number of buses and the acceptable (desired) limit (about 90 percent of the maximum). The capacities are less in the evening peak hour than in the morning because of the longer passenger service times associated with boarding passengers.

The dual bus lane operations on Madison and Fifth avenues have maximum capacities of about 225 and 200 buses during the morning and evening peak hours, respectively. The ac-

TABLE 8 SUGGESTED LIMITS FOR STREETS AND AVENUES
(MIDTOWN AREA)

AVENUE OR STREET	ESTIMATED MAXIMUM BUSES/HOUR	
	CAPACITY	DESIRED LIMIT
FIFTH AVE-MADISON AVE (1) (DUAL BUS LANES)	200 (AM)	180 (AM)
	180 (PM)	150 (PM)
SINGLE BUS LANE (WITH PASSING OPPORTUNITY - WIDE AVENUES)	120 (AM)	90 (AM)
	90 (PM)	80 (PM)
SINGLE BUS LANE (WITH NO PASSING OPPORTUNITY - I.E. NARROW AVENUES-CROSS STREETS)	80 (AM)	70 (AM)
	70 (PM)	60 (PM)
BUSES IN CURB LANE WITH MIXED TRAFFIC	70 (AM)	60 (AM)
	60 (PM)	50 (PM)

(1) 5TH AVE OPERATES LARGELY AS A DE FACTO DUAL BUS LANE

ceptable (or desired) levels of bus flow on these streets (limits) are 180 and 150 buses per hour during the morning and evening peak hour, respectively.

On Manhattan avenues (north-south streets) having a single bus lane, acceptable bus flow volumes of 90 buses per hour during the morning peak hour and 80 buses per hour during the evening peak hour appear reasonable.

Volume-Capacity Comparisons

Table 9 indicates that the actual number of buses on most Midtown avenues during the peak hour is less than the desired limit. The principal exceptions are Fifth, Madison, and Sixth avenues. However, if a dual bus lane were provided on Sixth Avenue, the peak flows would fall below the desired limits.

Table 10 indicates that bus flows on both Church Street and Broadway in Lower Manhattan approximate the desired limits for these streets.

The tables have several implications.

1. Buses on Madison and Fifth avenues operate at capacity with dual bus lanes. Therefore, no additional buses making passenger stops should be allowed on these streets during peak hours.

2. Sixth Avenue can accommodate additional buses if dual bus lanes are provided and right turns are prohibited during peak hours.

3. Lexington, Second, and Third avenues can accommodate more peak-hour buses.

4. Church Street and Broadway in Lower Manhattan appear to be unable to carry more buses in rush hours. Some gains might be achieved by limiting the number of cars on Broadway in the evening rush or providing dual bus lanes, and by running more buses nonstop on Church Street through Lower Manhattan.

Increasing Buses in the Manhattan CBD

The number of additional buses that could be effectively accommodated in the Manhattan CBD over the existing streets and with operational changes was estimated.

It was assumed that no changes would be made in street directions, but that certain operational changes would be made to accommodate additional express buses. It was also assumed that buses would receive and discharge passengers in the heart of Midtown. Therefore, the capacity reserves on the peripheral avenues (First, Second, Eighth, and Ninth) were not considered. These streets could accommodate additional buses, but they are too far from most passengers' destinations and, therefore, would have limited passenger attraction.

Table 11 gives the additional express buses that could be accommodated in the Manhattan CBD with certain operational changes and the likely orientation of the additional buses.

- Lexington Avenue, in conjunction with dual bus lanes on Sixth Avenue, could allow 30 more peak-hour buses each way. The buses probably would run to or from the Bronx.

- A pair of bus-taxi streets (53rd and 54th streets) could carry 60 more peak-hour buses each way. They could serve Queens and use Second and Third avenues for access to the Midtown Tunnel and Queensboro Bridge.

- A new Lower Manhattan bus terminal could serve at least 100 peak-hour buses from Brooklyn, Staten Island, and New Jersey.

Additional local buses could be accommodated on all north-south avenues except Lexington, Fifth, Sixth, and Madison avenues. The number of added peak-hour buses would range from about 25 on First Avenue to more than 70 on Tenth Avenue.

The 42nd Street transitway is planned to be built in two stages. The first stage will consist of dual eastbound bus lanes

TABLE 9 BUS VOLUME CAPACITY COMPARISONS, MIDTOWN (ABOUT 50TH STREET—ALL BUSES)

AM PEAK HOUR			
	OBSERVED PEAK BUSES/HOUR	DESIRED LIMIT	RESERVE
NORTHBOUND			
1ST AVE	50	90	40
3RD AVE	64	90	26
MADISON AVE	180	180	0
6TH AVE	142	90{a} [180]	-52 [38]
8TH AVE	50	90	40
10TH AVE	7	90	83
SOUTHBOUND			
2ND AVE	57	90	33
LEXINGTON	59	90	31
5TH AVE	164	180{e}	16
BROADWAY	36	90{d}	44
7TH AVE	63	90{d}	83
9TH AVE	7	90{d}	83
PM PEAK HOUR			
NORTHBOUND			
1ST AVE	40	80	40
3RD AVE	54	80	26
MADISON AVE	183	150{b}	-33
6TH AVE	102	80{c} [150]	-22 [48]
8TH AVE	60	80	20
10TH AVE	6	80	74
SOUTHBOUND			
2ND AVE	24	80	46
LEXINGTON	58	80	32
5TH AVE	196	150{a}	-46
BROADWAY	42	80{d}	38
7TH AVE	13	80{d}	77
9TH AVE	6	80{d}	74

NOTES: {a} Maximum Capacity 120
 {b} Maximum Capacity 180-200
 {c} Maximum Capacity 90
 {d} Assumes buses pre-empt curb lane
 {e} Maximum Capacity 200-225
 Note: When volumes exceed capacity, this implies recurrent "spillover" of buses into adjacent lanes.

[Figures in brackets show likely capacity gains from dual bus lane on 6th Ave (Avenue of the Americas)]

TABLE 10 BUS VOLUME-CAPACITY COMPARISONS, CHURCH STREET-BROADWAY, LOWER MANHATTAN, A.M.

	EXISTING PEAK HOUR BUSES	DESIRED LIMIT	RESERVE
CHURCH STREET	164	180(a)	16
BROADWAY	150	150(a)	0

(a) Estimated.

TABLE 11 ESTIMATED ADDITIONAL EXPRESS BUSES THAT COULD BE ACCOMMODATED IN CBD

STREET	OPERATIONAL CHANGE	ADDITIONAL BUSES		
		AM PEAK HOUR	PM PEAK HOUR	LIKELY ORIENTATION
LEXINGTON AVENUE	REROUTING	30	30) BRONX
SIXTH AVENUE	DUAL BUS LANES	30	30	
54TH STREET	ONE-WAY BUS STREETS	60	60) QUEENS
53RD STREET	BUSES RUN NON-STOP VIA 3RD-1ST AVE	60	60	
	TOTAL, MIDTOWN	180	180	
LOWER MANHATTAN TERMINAL	TOTAL, DOWNTOWN	100	100) BROOKLYN) STATEN ISLAND) NEW JERSEY
	TWO-WAY TOTAL	280	280	
	ONE-WAY TOTAL	190	190	

Source: Estimated

and a single westbound bus lane. These lanes largely would be preempted by the existing local and airport buses using 42nd Street. However, some reserve would be available. When the two-way transitway is built along the south side of 42nd Street (the second stage), it may be possible to operate more buses. The number of additional buses will depend on policy decisions about light rail versus bus operations.

Setting Limits on Gateways

The possibility of setting limits on the number of express buses entering Manhattan from outer boroughs and New Jersey was suggested in a study (2). Such limits do not appear necessary now because (a) the number of express buses entering Manhattan has declined in recent years; (b) bus flow is limited by the capacity of the major passenger boarding points within the business district, not at the gateways to Manhattan; and (c) enforcement would be difficult and probably would have to be done through the franchising process.

Moreover, new legislation would be required to establish the ceilings. It would be especially difficult to limit the number of buses coming from New Jersey, because these buses are certified to operate by the Interstate Commerce Commission, not by New York City.

Roads entering Manhattan operate at capacity. The increased bus volumes would displace cars. Whereas the automobile peak period might be lengthened, passenger productivity (i.e., passengers carried per lane per hour) would increase if more buses were in the traffic stream.

Because buses are more efficient users of street space than cars, car restrictions should take precedence over bus restrictions. Therefore, placing limits on the gateways to Manhattan becomes meaningful only if express bus volumes rise or as

part of the city's forthcoming strategies to reduce bus-induced congestion and improve air quality.

Substantial increases in the number of express buses entering Manhattan in peak periods could be accommodated if street and terminal space in Manhattan were adequate. Provision of bus-only lanes through the Brooklyn-Battery and Queens Midtown tunnels could enable 500 or more buses per hour to enter Manhattan, compared with less than 200 per hour today. However, the existing streets and terminal facilities could not handle these flows. Consequently, the number of additional peak-hour buses entering Manhattan should be compatible with the number that can be accommodated by the street system. An initial formulation of such limits by gateway is given in Table 12.

Table 12 indicates that the existing street system limits the number of buses entering Manhattan to 1,570. With operational improvements, this number could increase to 1,760. (The maximum observed volume in 1985 was 1,553.) A limit of 1,330 buses leaving Manhattan in the evening peak hour is indicated. With operational improvements, this could increase to 1,490. (The maximum observed volume in 1985 was 1,318.)

Setting Site-Specific Limits

The number of buses that any avenue can carry depends on the capacity and use of the key bus stops along the avenue and the stopping pattern of buses. The capacity of a stop depends on the number of loading positions and the bus dwell times. The bus dwell times, in turn, depend on the number of alighting and boarding passengers, method of fare collection, and bus door configuration.

Thus, a more desirable approach is to identify proposed stopping patterns and to determine whether existing stops

TABLE 12 SUGGESTED LIMITS FOR EXPRESS BUSES BY SECTOR, KEYED TO CAPACITIES OF EXISTING STREETS

A. AM PEAK HOUR - INBOUND			
SECTOR	MAXIMUM OBSERVED VOLUME	SUGGESTED LIMIT	
		EXISTING STREETS	OPERATIONAL IMPROVEMENTS
60TH STREET	228	230	260 (1)
BROOKLYN	205	210	260 (2)
QUEENS	216	220	280 (3)
SUBTOTAL	649	660	800
NEW JERSEY	904	910	960 (4)
TOTAL	1553	1570	1760

B. PM PEAK HOUR - OUTBOUND			
SECTOR	MAXIMUM OBSERVED VOLUME	SUGGESTED LIMIT	
		EXISTING STREETS	OPERATIONAL IMPROVEMENTS
60TH STREET	199	200	230 (1)
BROOKLYN	142	150	200 (3)
QUEENS	140	140	170 (2)
SUBTOTAL	481	490	600
NEW JERSEY	837	840	890 (3)
TOTAL	1318	1330	1490

NOTES: (1) Assumes Dual Bus Lanes - 6th Ave
 (3) Assumes 53-54th Bus-Taxi Streets
 (2) Assumes Battery Garage Bus Terminal

have the capacity to serve more buses. NYC DCP is pursuing this approach in reviewing new bus franchise applications. Pilot analyses—applying *Highway Capacity Manual* formulas—indicated that key bus stops along Madison and Fifth avenues operate at or near capacity during the evening peak period, depending on the acceptable probability of congestion. The analyses confirmed the desirability of not adding more express bus routes to these avenues (3).

Improving Operations

Operations and capacities can be improved in several ways.

1. Enforcement of bus lanes should be intensified. This is a productive use of resources in terms of the people benefited.
2. Fare collection practices should be modified. Widespread use of passes, express bus tokens, automatic fare cards, and fare boxes that accept dollar bills would reduce dwell times. A “pay as you exit” procedure on outbound trips would also reduce dwell times in the CBD.
3. Electronic fare boxes should be provided on all buses.
4. Articulated (or double-decked) buses should be considered for some of the longer expressway runs, such as the TA

service to Staten Island, because they can carry 25 to 35 percent more people per hour than conventional buses.

5. Providing better layover areas in Midtown would reduce deadhead bus flows.

IMPLICATIONS AND DIRECTIONS

The following directions emerge from the analyses of express bus operations in the Manhattan CBD.

1. Manhattan’s local buses serve a market different from that served by parallel subway lines. Passenger trips are short (median 1.0 to 1.2 mi) and are not easily transferable to subway. Thus, it is not practical to remove local buses from key avenues to allow more space for express buses.
2. Express buses constitute the bulk of the bus volumes entering the Manhattan CBD and on Manhattan avenues. They are concentrated on Fifth, Madison, and Sixth avenues in Midtown, and on Broadway and Church Street in Lower Manhattan. These avenues penetrate the major employment concentrations. Eight of every 10 Midtown-destined bus riders have destinations between Third and Eighth avenues. Although some express buses may be diverted to peripheral

streets, most bus companies want to run buses on Fifth, Sixth, and Madison avenues, because these streets serve areas where most riders want to go.

3. It is not desirable to set limits on the number of express buses that can enter or leave the Manhattan CBD during peak hours. Setting limits for bus flows at gateways to Manhattan would become appropriate only as part of NYCDOT's overall Manhattan congestion-reduction program or if express bus volumes rise substantially. The key issue is one of accommodating buses at major boarding points rather than at gateways. Bus flows are critical in the Manhattan CBD, where heavy passenger boarding and alighting take place, not at the gateways. (The exception is Fifth Avenue north of 57th Street in the morning, where buses are limited to a single lane.) In addition, the number of express buses entering or leaving the Manhattan CBD has declined in the last few years, enforcement of such a ceiling could prove difficult, and legal problems could result from setting a ceiling.

4. There is little, if any, space for additional buses in the Manhattan CBD during peak hours on Madison, Fifth, and Sixth avenues in Midtown, and along Broadway and Church Street in Lower Manhattan.

5. The best way to assess the ability of a street to carry more buses is to evaluate the capacity and use of each stop and to determine whether existing stops can serve additional buses. Key questions to be addressed on a site-specific basis are the following: Where will new express bus routes run? Where will they receive and discharge passengers? Is there enough curb-loading space at specific stops to handle the additional buses? Pilot analyses indicated that key express bus stops along Fifth and Madison avenues were operating at or near capacity. Bus lanes along Broadway and Church Street in downtown Manhattan also operate at capacity.

6. Intensified enforcement, improved fare collection practices, widespread use of electronic fare boxes, articulated bus

operations, and better layover practices could improve bus flows on Manhattan streets and avenues.

Analysis of potential markets indicates relatively limited opportunities for additional express service. Thus, major growth in express buses on Manhattan streets is not likely, and major restrictions on additional buses on Manhattan avenues are not essential at present.

Continued improvements in subway service, such as station modernization, new cars, and signal control changes, will affect future bus ridership, making the likelihood of dramatic increases in express buses on Manhattan streets even more remote. Finally, if a limit is to be implemented, perhaps cars rather than buses should be restricted.

ACKNOWLEDGMENT

This paper is part of the *Express Bus Service Plan* study prepared for NYC DCP by Polytechnic University.

REFERENCES

1. *Special Report 209: Highway Capacity Manual*. TRB, National Research Council, Washington, D.C., 1985.
2. *Express Bus Route Policy Study*. URA Company, Inc., New York, 1986.
3. L. F. Marshall, H. S. Levinson, L. C. Lennon, and J. Cheng. Bus Service Times and Capacities in Manhattan. In *Transportation Research Record 1266*, TRB, National Research Council, Washington, D.C., 1990, pp. 189–196.

The views in this paper express those of the authors and do not represent those of the city of New York.

Publication of this paper sponsored by Committee on Bus Transit Systems.