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Subject: Impact of Congestion on Metrobus Operations

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This memorandum presents an analysis of recent trends in bus travel times, peak hour service frequency, and peak vehicle requirements for 24 of the highest frequency (and highest ridership) lines in the Metrobus system. The goal of this analysis is to gauge the effect of traffic congestion and passenger crowding on bus operations. The hypothesis of this analysis is that external factors, such as traffic congestion, impose a cost on Metrobus by slowing down the buses and therefore increasing the peak vehicle requirements in order to maintain the same frequency. Growth in ridership, while a desired outcome of bus service, also imposes a cost, as additional trips must be operated to avoid overcrowding.

Findings

The analysis presented below provides some evidence that traffic congestion does impose a cost on Metrobus in terms of increasing the peak vehicle requirement for a given level of service. Growth in passenger demand also imposes a cost as more trips are added to popular routes to avoid overcrowding. The line that provides the clearest evidence of the cost of congestion is the North Capitol Street line (80) where the afternoon peak vehicle requirement has risen by 3 since 2000 to accommodate a 12.5 minute increase in the average scheduled running time. The U Street-Garfield line (90,92,93) exhibits a similar pattern. Other lines, such as the Greenbelt-Twinbrook line (C2,4), the Pennsylvania Avenue line (30s), and the Veirs Mill Road line (Q2) demonstrate that a combination of traffic congestion and passenger demand leads to increased vehicle requirements.

Data Sources

In order to establish trends in travel times, service frequency, and vehicle requirements, TranSystems used data obtained during the Regional Bus Study, new data from the Metrobus Network Evaluation, and supplemental data from paper files in the Metrobus operations planning office. Metro does not retain historical data on peak vehicle requirements beyond two years, but fortunately Transystems' files from the Regional Bus study contained this information.

The endpoints of the analysis were set as 2000 and 2006, with an intermediate data point in the vicinity of 2003. Metrobus schedules do not all change at the same time, so there was some flexibility in the choice of dates. For example, if the schedule for a given line changed at the beginning of 2004 rather than in 2003, the later date was chosen. The earliest figures available for peak vehicle requirements were from June 2001.

Peak travel times and peak hour frequencies were drawn from line headway sheets and/or Passenger-Time Survey reports. The latter reports, which are an output of the SMART ridecheck data system, offered an easier means of extracting the data, so they were used whenever available.

Selection of Lines

A total of 24 lines were selected for analysis. These lines generally had the highest peak vehicle requirements, and often the highest ridership. The list of lines was long enough to contain representatives from all of the WMATA Compact jurisdictions. Among these lines, only the Massachusetts Avenue line (N2,4,6) appeared to have undergone a major service change that made the data from 2000 not comparable with later years, especially with respect to travel times.

The selected lines are shown in Table 1 below. Together, these lines comprise some 44% of systemwide weekday peak ridership and 37% of the Metrobus peak vehicle requirement.

Table 1: Lines Selected for Analysis

Route Number	Line Name	Juris	Peak Period Riders	AM Peak Vehicles
30,32,34-36	Pennsylvania Ave	DC	12,326	45
42	Mt Pleasant	DC	4,512	17
52-54	14th St	DC	9,146	23
70,71	Georgia Ave-7th St	DC	10,780	17
80	North Capitol St	DC	5,043	14
90,92,93	U St-Garfield	DC	8,557	25
96,97	East Capitol St-Cardozo	DC	2,965	14
A2-48	Anacostia-Congress Heights	DC	6,210	19
B2	Bladensburg Rd-Anacostia	DC	4,812	15
D1,3,6	Sibley Hospital-Stadium/Armory	DC	4,835	28
D12-14	Oxon Hill-Suitland	DC	3,075	12
H2-4	Crosstown	DC	4,479	17
N2-4,6	Massachusetts Ave	DC	2,558	17
S2,4	16th St	DC	8,478	26
V7-9	Minnesota Ave-M St	DC	3,134	14
W4	Deanwood-Alabama Ave	DC	3,182	14
X2	Benning Rd-H St	DC	8,899	13
C2,4	Greenbelt-Twinbrook	MD	7,182	19
F4,6	Prince George's-Silver Spring	MD	5,137	16
J1-3	Bethesda-Silver Spring	MD	4,036	14
Q2	Veirs Mill Rd	MD	5,620	15
7A-F,H,P,W,X	Lincolnia-North Fairlington	VA	3,467	24
16A,B,D-F,J	Columbia Pike	VA	4,113	14
17G,H,K,L	Kings Park Express	VA	962	15

Trends in Travel Time

Ideally, a travel time analysis would have compared actual average travel times from the three target years. Unfortunately no such data was available, though, in the future, the recently installed AVL system should be able to provide this information. Instead, this analysis was based on *scheduled* travel times in the morning and afternoon peak periods. The implicit assumption is, therefore, that service planners and schedulers adjust the scheduled time to reflect operating conditions. Of course, this is only done periodically, so there can be a lag of months or even years before a schedule is changed in response to a change in traffic conditions in a corridor.

Many of the lines listed above consist of several routes, and each of these have different travel times. In addition, some of the routes have multiple patterns (denoted by a slash "/" or a pattern number "*2"), which also have

distinct travel times. All comparisons made in this analysis take account of these differences. As shown below in Table 2, a summary number of travel time change is shown for each line. This summary figure is the average of the travel time changes for all of the individual routes and patterns that make up the line. If new routes/patterns were introduced (or old ones discontinued) between 2000 and 2003, or 2000 and 2006, they were excluded from the analysis. As mentioned earlier, it appears that the routes that make up the Massachusetts Avenue line changed drastically between 2000 and 2003 (the N6 disappeared from the peak and the N3 appeared, and the travel times for the N2 and N4 changed by more than 50%), so that travel time comparisons for this route were not considered valid. For each peak period for each route/pattern and for each direction, the longest scheduled travel time was selected as the data point.

Table 2: Change in Running Time

Route	Name	Juris	Change in Running Time (minutes) 2000-2003		Change in Running Time (minutes) 2000-2006	
			AM	PM	AM	PM
30,32,34-36	Pennsylvania Ave	DC	3.75	4.00	3.75	4.20
42	Mt Pleasant	DC	4.67	3.33	4.67	3.33
52-54	14th St	DC	1.00	1.00	1.00	3.67
70,71	Georgia Ave-7th St	DC	0.00	0.00	0.00	0.00
80	North Capitol St	DC	0.50	4.50	6.00	12.50
90,92,93	U St-Garfield	DC	1.25	1.50	3.75	3.25
96,97	East Capitol St-Cardozo	DC	0.00	2.25	0.00	2.25
A2-48	Anacostia-Congress Heights	DC	1.13	1.83	1.13	1.83
B2	Bladensburg Rd-Anacostia	DC	-0.50	-3.00	2.50	-3.00
D1,3,6	Sibley Hospital-Stadium/Armory	DC	1.33	4.50	1.33	4.50
D12-14	Oxon Hill-Suitland	DC	-1.00	1.75	-1.00	1.75
H2-4	Crosstown	DC	0.00	0.00	0.00	0.00
S2,4	16th St	DC	-0.20	-0.50	-0.20	0.00
V7-9	Minnesota Ave-M St	DC	3.00	5.33	3.00	5.33
W4	Deanwood-Alabama Ave	DC	1.75	2.00	1.75	2.00
X2	Benning Rd-H St	DC	0.00	3.00	3.00	2.50
C2,4	Greenbelt-Twinbrook	MD	1.75	3.50	2.75	6.75
F4,6	Prince George's-Silver Spring	MD	-1.50	-1.75	-1.50	-1.75
J1-3	Bethesda-Silver Spring	MD	0.00	0.00	1.20	3.60
Q2	Veirs Mill Rd	MD	0.00	0.00	2.50	4.00
7A-F,H,P,W,X	Lincolnia-North Fairlington	VA	1.10	1.67	1.10	2.44
16A,B,D-F,J	Columbia Pike	VA	2.00	1.50	4.88	4.25
17G,H,K,L	Kings Park Express	VA	0.00	0.00	0.00	0.00

The figures in Table 2 do not reveal a single regionwide pattern in scheduled travel times. Five lines had no change in scheduled running time between 2000 and 2003, and three of these lines still had no change through 2006. Four lines actually had decreases in running times during this span; perhaps these schedules had been too generous with running time back in 2000 and had resulted in many early arrivals.

The majority of lines, however, did exhibit small to moderate increases in running times, mostly in the range of 1 to 3 minutes. The increases from 2000 to 2006 are generally larger than the increases from 2000 to 2003, as one would expect. The lines with the largest increases in running time are the North Capitol Street line (80), the Greenbelt-Twinbrook line (C2,4) and the Minnesota Avenue-M Street line (V7-9).

It seems clear from this first stage of the analysis that increasing regional traffic congestion is imposing a cost on Metrobus operations. The rest of the memorandum will help to estimate the magnitude of that cost.

Trends in Service Frequency

Along with running time, the frequency of service is a key determinant of vehicle requirements, and so the relationship between running time and vehicles must take into account any change in frequency. Many Metrobus lines operate at irregular frequencies (a 14-minute interval between buses, followed by a 17-minute interval, then a 16-minute interval, and so on) so it is sometimes difficult to determine exactly what the frequency is. Therefore, for the purpose of this analysis, frequency is defined as the number of trips in the peak hour of service. In most cases, the morning peak hour was from 7:00 a.m. to 7:59 a.m. and the afternoon peak hour was from 4:30 p.m. to 5:29 p.m. However, if it was clear for a given route that the peak hour was slightly earlier or later, that peak hour was used instead. Peak hour trips are shown separately for each direction (inbound and outbound). Metrobus routes do not have official inbound and outbound designations, but rather use compass directions (eastbound, northbound, etc.). In this memorandum, it was assumed that the direction toward downtown Washington was inbound. For crosstown-oriented lines, the inbound direction was assumed to be that direction that had the greater number of morning trips. Table 3 shows the number of trips by period by direction for each of the three analysis years.

Table 3: Peak Hour Trips by Period and Direction

Route Number	Peak Hour Trips 2000				Peak Hour Trips 2003-4				Peak Hour Trips 2006				Change 2000-2006			
	AM In	AM out	PM In	PM out	AM In	AM out	PM In	PM out	AM In	AM out	PM In	PM out	AM In	AM out	PM In	PM out
30,32,34-36	17	10	14	9	19	12	12	14	20	14	9	13	3	4	-5	4
42	18	6	8	13	18	6	9	13	19	6	9	13	1	0	1	0
52-54	15	9	8	15	15	7	11	13	15	7	11	12	0	-2	3	-3
70,71	8	7	6	8	8	7	6	8	8	7	6	8	0	0	0	0
80	7	4	4	6	6	4	4	5	7	4	4	6	0	0	0	0
90,92,93	14	8	8	12	14	8	8	12	15	6	6	12	1	-2	-2	0
96,97	10	7	8	7	10	7	8	7	8	8	8	8	-2	1	0	1
A2-48	24	12	10	22	24	12	10	22	22	15	14	21	-2	3	4	-1
B2	9	6	6	6	11	6	6	6	11	6	6	5	2	0	0	-1
D1,3,6	12	9	7	9	13	8	7	6	11	7	6	7	-1	-2	-1	-2
D12-14	6	5	4	5	6	3	4	6	7	6	5	6	1	1	1	1
H2-4	11	7	6	8	11	7	6	8	13	7	6	9	2	0	0	1
N2-4,6	10	4	4	8	11	4	6	8	12	4	6	9	2	0	2	1
S2,4	13	6	11	15	13	6	14	15	17	6	15	15	4	0	4	0
V7-9	8	5	4	7	9	7	4	7	8	7	4	7	0	2	0	0
W4	10	4	4	4	9	5	4	4	7	4	4	4	-3	0	0	0
X2	9	7	9	10	9	8	9	10	9	10	7	9	0	3	-2	-1
C2,4	6	6	6	6	7	6	8	8	10	6	7	8	4	0	1	2
F4,6	6	6	6	6	6	6	6	6	7	6	6	6	1	0	0	0
J1-3	12	5	7	11	12	5	7	11	10	7	6	8	-2	2	-1	-3
Q2	7	5	6	5	7	5	6	5	8	5	6	7	1	0	0	2
7A-F,H,P,W,X	28	8	6	24	26	8	6	24	26	8	7	22	-2	0	1	-2
16A,B,D-F,J	12	11	5	12	12	11	6	12	10	6	5	10	-2	-5	0	-2
17G,H,K,L	11	0	0	14	11	0	0	14	11	0	0	14	0	0	0	0
Total	283	157	157	242	287	158	167	244	291	162	163	239	8	5	6	-3

Overall, there was a slight increase in the number of peak period trips offered on these lines, except in the outbound direction in the afternoon. Morning inbound service increased the most, with reverse peak service increasing at a slower rate, except for the A2-48 line which saw an increase in reverse peak service and a slight drop in peak direction service.

It is important to note that the Columbia Pike line (16A,B,D-F,J) appears to have diminished service compared to 2000, but this is because of the broad restructuring in the corridor that took place in 2003, introducing a new Metrobus line (16G,H,K,W) and new complementary ART services. The overall large increase in total corridor service allowed for a minor reduction in service on the original Columbia Pike line. The apparent drop in outbound service on the 52-54 line reflects another restructuring plan which substituted fewer longer trips for more frequent short trips. There have been other restructuring efforts that have affected some of these lines, but these have not been accounted for in detail. If all of the lines that had service changes in the past six years had been excluded, there would have been a much smaller pool for analysis.

Trends in Peak Vehicle Requirements

The final piece of the puzzle is the number of peak vehicles required to operate the service. These figures are taken directly from Metrobus reports and thus use WMATA definitions on how many buses are assigned to each line.

Table 4: Change in Peak Vehicles

Route Number	Name	2001 vehicles		2004 vehicles		2006 Vehicles		Change 2001-2006	
		AM	PM	AM	PM	AM	PM	AM	PM
30,32,34-36	Pennsylvania Ave	43	42	44	41	45	43	2	1
42	Mt Pleasant	16	14	17	16	17	16	1	2
52-54	14th St	20	22	22	24	23	25	3	3
70,71	Georgia Ave-7th St	17	20	17	21	17	18	0	-2
80	North Capitol St	13	12	13	14	14	15	1	3
90,92,93	U St-Garfield	23	21	23	25	25	25	2	4
96,97	East Capitol St-Cardozo	13	11	14	12	14	13	1	2
A2-48	Anacostia-Congress Heights	23	18	19	20	19	21	-4	3
B2	Bladensburg Rd-Anacostia	14	13	15	14	15	14	1	1
D1,3,6	Sibley Hospital-Stadium/Armory	25	19	28	18	28	18	3	-1
D12-14	Oxon Hill-Suitland	13	12	12	13	12	13	-1	1
H2-4	Crosstown	17	13	17	12	17	12	0	-1
N2-4,6	Massachusetts Ave	17	14	17	13	17	13	0	-1
S2,4	16th St	26	26	26	29	26	30	0	4
V7-9	Minnesota Ave-M St	13	14	14	14	14	14	1	0
W4	Deanwood-Alabama Ave	13	10	14	10	14	10	1	0
X2	Benning Rd-H St	12	14	12	16	13	15	1	1
C2,4	Greenbelt-Twinbrook	15	16	19	20	19	21	4	5
F4,6	Prince George's-Silver Spring	14	17	16	16	16	17	2	0
J1-3	Bethesda-Silver Spring	15	16	14	12	14	14	-1	-2
Q2	Veirs Mill Rd	14	17	12	15	15	18	1	1
7A-F,H,P,W,X	Lincolnia-North Fairlington	19	18	24	18	24	18	5	0
16A,B,D-F,J	Columbia Pike	15	14	15	16	14	13	-1	-1
17G,H,K,L	Kings Park Express	16	16	14	15	15	15	-1	-1
Total		426	409	438	424	447	431	21	22

Overall, there has been a significant increase in peak vehicles for this group of lines, amounting to about 5%. Table 5 below attempts to establish relationships between the changes in peak vehicle requirements and the potential causes we have looked at so far.

Table 5: Summary of Factors

Routes	Name	Change in Vehicles		Change in Peak Hour Trips				Change in Running Time (minutes)	
		AM	PM	AM In	AM out	PM In	PM out	AM	PM
C2,4	Greenbelt-Twinbrook	4	5	4	0	1	2	2.75	6.75
90,92,93	U St-Garfield	2	4	1	-2	-2	0	3.75	3.25
S2,4	16th St	0	4	4	0	4	0	-0.20	0.00
52-54	14th St	3	3	0	-2	3	-3	1.00	3.67
80	North Capitol St	1	3	0	0	0	0	6.00	12.50
A2-48	Anacostia-Congress Heights	-4	3	-2	3	4	-1	1.13	1.83
42	Mt Pleasant	1	2	1	0	1	0	4.67	3.33
96,97	East Capitol St-Cardozo	1	2	-2	1	0	1	0.00	2.25
30,32,34-36	Pennsylvania Ave	2	1	3	4	-5	4	3.75	4.20
B2	Bladensburg Rd-Anacostia	1	1	2	0	0	-1	2.50	-3.00
X2	Benning Rd-H St	1	1	0	3	-2	-1	3.00	2.50
Q2	Veirs Mill Rd	1	1	1	0	0	2	2.50	4.00
D12-14	Oxon Hill-Suitland	-1	1	1	1	1	1	-1.00	1.75
7A-F,H,P,W,X	Lincolnia-North Fairlington	5	0	-2	0	1	-2	1.10	2.44
F4,6	Prince George's-Silver Spring	2	0	1	0	0	0	-1.50	-1.75
V7-9	Minnesota Ave-M St	1	0	0	2	0	0	3.00	5.33
W4	Deanwood-Alabama Ave	1	0	-3	0	0	0	1.75	2.00
D1,3,6	Sibley Hospital-Stadium/Armory	3	-1	-1	-2	-1	-2	1.33	4.50
H2-4	Crosstown	0	-1	2	0	0	1	0.00	0.00
N2-4,6	Massachusetts Ave	0	-1	2	0	2	1		
16A,B,D-F,J	Columbia Pike	-1	-1	-2	-5	0	-2	4.88	4.25
17G,H,K,L	Kings Park Express	-1	-1	0	0	0	0	0.00	0.00
70,71	Georgia Ave-7th St	0	-2	0	0	0	0	0.00	0.00
J1-3	Bethesda-Silver Spring	-1	-2	-2	2	-1	-3	1.20	3.60

This table is sorted in descending order of the change in peak vehicles, PM first, then AM. Service on the C2,4 line has been increased in the peak periods, and running times have lengthened, partly because of traffic congestion, and partly due to dwell time delays caused by heavy passenger loads. Increased travel demand in the University Boulevard corridor, both for auto and transit, has clearly increased the cost of this service for Metrobus. The U Street-Garfield line (90,92,93) has seen only a slight increase peak direction trips and a decrease in reverse peak trips, but travel time has gone up by over three minutes per trip on average. Thus, this line also seems to be a case where roadway congestion has imposed a cost on Metrobus on the order of 2 more AM buses and 4 more PM buses. Peak service on the 16th Street line (S2,4) has increased, but travel times have not. In this case, it would seem that roadway congestion is a less important factor than passenger demand and overcrowding.

As mentioned earlier, the 14th Street line (52-54) has been restructured, so that it is difficult to attribute the large increase in peak vehicles to a specific cause, though running time in the afternoon has increased by more than 3 minutes per trip. The North Capitol Street line (80) is perhaps the clearest case of the cost of congestion. The number of peak trips on this line has not increased at all, but scheduled running times have been extended by 6

minutes in the morning and more than 12 minutes in the afternoon. These running time increases have led to the need for more vehicles to be able to maintain the existing level of service. The Mt. Pleasant line (42) seems to follow much the same pattern as the 80, with above average increases in travel time but little change in the level of service.

For the Pennsylvania Avenue line (30s), both factors, passenger demand and traffic congestion seem to be at work. The same is true for the Veirs Mill Road line (Q2), and the Bladensburg Rd-Anacostia line (B2) in the morning. The Lincolnia-North Fairlington line may have undergone some restructuring causing a need for more peak vehicles, as the service level and morning travel time do not correlate with a large increase in peak vehicles.